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STUDIES ON SUBSURFACE MOVEMENT OF EFFLUENT FROM PRIVATE SEWAGE DISPOSAL SYSTEMS USING RADIOACTIVE AND DYE TRACERS

Dr. M. Brandes

Interim Report - Part 1
1972

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761
.B73
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1973

Ontario
Ministry of the Environment

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ONTARIO MINISTRY OF THE ENVIRONMENT

STUDIES ON SUBSURFACE MOVEMENT OF EFFLUENT FROM PRIVATE SEWAGE DISPOSAL SYSTEMS USING RADIOACTIVE AND DYE TRACERS

(Interim Report - Part 1)
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By

Dr. M. Brandes, P. Eng.

Private Waste and Water

Management Branch

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PREFACE

BY

N. D. PAPPAS, P.Eng.

As part of the Technical Services program of the Private Waste and Water Management Branch, the work reported on herein is concerned with the observation of the sub-surface movement of traced private sewage disposal system effluents and the determination of the efficiency of the soil mantle as a treatment medium.

During the 1972 period covered by this interim report a start was made on studying the migration of nutrients, principally phosphorous, through the soil and ground water, to determine, by field measurements, the degree of fixation in certain types of soils media.

During the 1973 period (results being compiled), some improvements were made to the techniques, and more positive correlations will be obtained with substantiation of the results reported upon herein.

It is expected that the methods as now developed will be used in 1974 to 1976 as part of the Ministry of the Environment contribution to the IRGOLD project, Activity 3 of Task C to determine the significance and magnitude of material inputs to river basins from private sewage disposal systems in densely developed recreational areas in the Precambrian Shield and other areas of shallow overburden. Other studies under this reference are planned in municipalities without organized sewage collection systems in Southwestern Ontario.

INDEX

List of Appendices I

Abstract II

1. Introduction 1

2. Purpose of Study 4

3. Phosphorus and Nitrogenous Compounds in Soil and Water . 5

3.1 Phosphorus 5

3.2 Nitrogen 8

4. Study Area 11

4.1 Location of Cottages 11

4.2 Selection of Lots for Tracer Study 13

5. Methods and Techniques 14

5.1 Tracing and Tracers 14

5.2 Location and Arrangement of Bore Holes 18

5.3 Sampling and Analysis 19

6. Results 22

6.1 General 22

6.2 Group I Sewage Disposal Systems 22

6.3 Group II Sewage Disposal Systems 25

6.4 Combined Results (I and II Group of Cottages) . . . 26

6.5 Phosphates and Nitrates in Ground Water Samples . . 29

7. Discussion 32

7.1 Movement and Detectability of Tritium in the Ground Water 32

7.2 Advantages of the Use of Tritium 33

7.3 Movement and Detectability of Radioactive Phosphorus (P-32) in Ground Water 33

8. Conclusions 38

8.1 Effect of Distances of Private Sewage Disposal Systems from Receiving Water on Sewage Treatment Efficiency 38
a. Phosphorus Removal 38
b. Nitrates Removal 39
c. Removal of Coliform Organisms 39

8.2 Effect of Ground Water Depth on Sewage Treatment Efficiency 40

8.3 Soil Type 40

8.4 Effluent Travel Time 40

8.5 Tracers 41

8.6 Future Work 41

9. Acknowledgment 42

10. References 43

11. Appendices

LIST OF APPENDICES

Appendix	I	Tracer Study Site Plans
Appendix	II	Soil Characteristics
Appendix	III	Laboratory Results
Appendix	IV	Graphs-Movement of Radio-active Tracers through soil

STUDIES ON SUBSURFACE MOVEMENT OF EFFLUENT FROM PRIVATE SEWAGE DISPOSAL SYSTEMS USING RADIOACTIVE AND DYE TRACERS

(abstract)

The underground movement of septic tank effluent between the tile field and the receiving body was studied by using Tritium (^{3}H), Radioactive Phosphorus (P-32) and Fluoresceine, as tracers.

All the three tracers were introduced at the same time into the outlets of the septic tanks of eleven sewage disposal systems. Daily ground water samples were collected from 41 specially cased and protected bore holes for more than six months. About 3500 water samples were tested for radioactivity, dye concentration, phosphates and nitrates concentration and for total and faecal coliforms.

Tritium was detected in ground water samples taken from 10 of the bore holes, P-32 was detected only in one bore hole drilled very close or within the tile field area.

The detection of tritium in bore holes made it possible to determine the time required for the effluent to reach the receiving body.

In undisturbed uniform soil containing more than 40% of silt and clay faecal coliforms were detected in bore holes located at distances up to 55 feet (16.5 m) from tile field, but not beyond. The time to travel the distance of 55 feet was longer than the survival time of Escherichia coli in underground environment reported in the literature.

Ninety-eight percent of decrease in phosphorus concentration in ground water (from 15 mg/l to 0.3 mg/l as P) took place within the first 10 feet (3.05 m) from tile field in the same soil conditions. A further decrease to 0.1 mg/l in a distance of 60 feet from tile field was observed.

Fluorescein did not move more than a few feet in undisturbed soil containing more than 40% of silt and clay.

STUDIES ON SUBSURFACE MOVEMENT OF EFFLUENT FROM PRIVATE SEWAGE DISPOSAL SYSTEMS USING RADIOACTIVE AND DYE TRACERS

PART 1 - 1972

1. INTRODUCTION

Increased development in Ontario has been a cause for concern of the public and authorities for preserving the high quality of surface and ground waters.

Some observations reported by literature (1,2) indicate that a continuous process of enrichment of lake waters with nutrients takes place which stimulate a luxuriant growth of plants causing deterioration of surface water quality. Phosphorus and nitrogen appear to be the most important among the nutrients responsible for such enrichment.

One of the factors responsible for nutrient input to surface waters is human activity, however, there are some indications that nutrients from natural sources accumulated for ages in bottom sediments constitute a vast reservoir capable of supporting aquatic plant growth even if the input of nutrients is shut off. (3)

When estimating the contribution of different sources to Lake Mendota water eutrophication, Lee (1) demonstrated that municipal and industrial waste water, together with rural run-off, contribute to 78% of phosphorus reaching the lake; 72% of nitrogen is coming from ground water and precipitation on the lake surface. The contribution of private sewage disposal systems to the nutrient enrichment of this lake

seems to be relatively low.

In order to protect the ground and surface waters from contamination, the private sewage disposal systems must be capable of reducing the concentration of contaminants to an acceptable level.

The concentration of total phosphorus in domestic waste water before treatment is about 5-20 mg/l (as P) (4).

According to Volleweider (2), a body of water is in danger with regard to its trophic level when the concentrations of total phosphorus and bound inorganic nitrogen are in excess of 0.01 mg P/l and 0.3 mg N/l respectively.

It is generally accepted that the greatest source of contamination of surface waters and ground waters with waterborne pathogenic organisms is from human activity. Human excreta may contain very large numbers of different pathogens which when reaching such waters can become a source of diseases.

The organisms most commonly used as indicators of faecal pollution of water are the coliform group as a whole and particularly Escherichia coli which is the most frequent type of coliform organism present in human and animal intestines. Escherichia coli is found in numbers up to 100×10^6 or even 1000×10^6 per gram of fresh feces (5). When diluted in water from bath, laundry and kitchen and after the organic matter is decomposed and settled in septic tanks, coliform counts in the effluent from such tanks are reduced to about 30×10^6 to 300×10^6 of total coliforms and to about 8×10^6 of faecal coliforms per 100 ml. (6,7).

The permissible density of coliform organisms in final effluent to be discharged into water body(ies) is not defined.

According to the Canadian Drinking Water Standards and Objectives 1968 (8), the Maximum Permissible Limits of coliform counts recommended for raw water sources are 5000 total coliforms and 1000 faecal coliforms per 100 ml of water. The maximum limit of coliform organisms in water used for body contact recreational purposes, recommended by the Ministry of the Environment Guidelines (9), is 1000 total Coliform Organisms (MPN and 100 faecal Coliform Organisms per 100 ml of water.

Accordingly, to afford the necessary protection to lakes, rivers and ground water, distances of private sewage disposal systems from lakes and rivers, depth to ground water and the quality of soil serving as a filter, must provide capability of the system to decrease the level of contaminants in the ground water transporting the septic tank effluent towards the water body.

2. PURPOSE OF STUDY

The purpose of this study is:

1. to obtain data for determination of the effect of:
   a) Distances of Private Sewage Disposal Systems from receiving waters.
   b) Ground water depth.
   c) Soil type.
   d) Effluent travel time,

   on sewage treatment efficiency, by carrying out the necessary field and laboratory experiments and,
2. to develop simple and practical methods for classifying existing sewage disposal systems.

3. PHOSPHORUS AND NITROGENOUS COMPOUNDS IN SOIL AND WATER

1. Phosphorus

As mentioned phosphates and nitrates discharged into lake water cause an acceleration in growth of algae and larger aquatic life. The excessive vegetation decomposes and consumes the deep-water oxygen vital for fish and other animal life.

A consistent increase in Total Phosphorus levels in lakes is reported by literature. Table 1 presents a comparison of Total Phosphorus levels in Connecticut lakes in 1940 and 1969 (10)

Table 1

(concentration in mg/l as P)

Reference	Eastern Highland	Western Highland	Central Lowland
Deevey (1940)	0.0108	0.0130	0.0200
Benoit (1969)	0.0167	0.0243	0.0247

According to the author, the increase in phosphorus shown in Table 1 over the 25-year period "cannot be attributed to geochemical processes other than those involving human ecology".

Human sewage from inadequate individual sewage systems located along lake shores contains nutrients and can contribute, in some degree, to eutrophication of lakes if the purification ability of the soil between the sewage disposal system and the lake is insufficient.

As it is demonstrated by some sources (1) most of the phosphates and nitrates are not coming into the lakes from individual septic tank systems, they come mostly from farm manure that is spread on frozen ground during the winter and from runoff from urban areas which are rich in phosphates and nitrates.

The extent of removal of phosphorus by private sewage disposal systems and especially by the soil separating the tile field from the lake is of special interest.

In natural systems, phosphorus exists in combination with oxygen and different cations. In most cases the phosphorus is in the orthophosphate form where the phosphorus atom is surrounded by 4 oxygen atoms and by sufficient cations to balance the charges, e.g. in trisodium orthophosphate Na_3PO_4 or dicalcium orthophosphate $CaHPO_4$.

Numerous schemes of phosphate removal processes are discussed in literature (4,10,11). As shown, almost all phosphate removal processes stem from simple, fundamental relationships.

The Septic-Tank-Soil System can be grouped under one of the following two categories: a) phosphate removal by microbiological means, b) phosphate removal by chemical or physical means (i.e. by chemical precipitation or sorption).

The effect of microbiological removal of phosphate is relatively high only when the activated sludge process is applied (up to 90% of phosphate removal), or when spray irrigation flow is used and an aerobic biodegradation takes place (76 to 93% of phosphate removal) (12). Only a fraction of the phosphorus and nitrogen of domestic waste water is removed by microorganisms

under conventional waste water treatment (11). It is interesting to note that the phosphorus removal by microbiological means is in excess of any known stoichiometric ratio probably because the phosphorus is stored within the microorganisms (11). The process is not well known yet.

The solubility equilibria and sorption phenomena were explained by Stumm in 1962 (13) and Hsu in 1965 (14). Many metal ions are particularly effective in precipitating phosphate from solution. The three metals contributing mostly to phosphate precipitation are: calcium, iron and aluminium. All three of these metals form relatively insoluble precipitates with phosphate.

Table 2 presents some chemical reactions for elimination of phosphates in sewage treatment plants (after Stumm 13).

Table 2

Relatively insoluble precipitates with phosphate. (after Stumm 13)

Number	Reaction
1	$Fe^{+3} + PO_4^{-3} = FePO_4$
2	$3Fe^{+2} + 2PO_4^{-3} = Fe_3(PO_4)_2$
3	$Al^{+3} + PO_4^{-3} = AlPO_4$
4	$Ca^{+2} + 2H_2PO_4^{-2} = Ca(H_2PO_4)_2$
5	$Ca^{+2} + HPO_4^{-2} = CaHPO_4$
6	$10CA^{+2} + 6PO_4^{-3} + 20H^{-1} = Ca_{10}(OH)_2(PO_4)_6$

The soil acts chemically similar to the reactions that are being developed for phosphorus removal in sewage treatment plants. Cations, calcium, iron and aluminium, existing naturally in soil, are particularly responsible for precipitating phosphorus from the septic tank effluent moving through soil (15). The efficiency of phosphate removal depends on the concentration of these cations in soil and on the pH conditions (11).

Hsu (14) discussed the mechanism of phosphorus fixation in soils of different pH conditions. In acid soils, sorptions of phosphate on aluminium hydroxides and iron oxides rather than solubility of phosphate compounds seems to dominate while in neutral and basic soils, the iron phosphate and aluminium phosphate interactions are replaced by calcium phosphate. Solubility of phosphate probably dominates over sorption phenomena.

In their final report on the use of soil mantle as a waste-water treatment system McGauhey and Krone (16) state that "under normal conditions of soil pH, phosphates are effectively removed." Also Weber (15) came to similar conclusions on immobilisation and fixation of phosphorus in soil attributing the immobility to the aluminium, iron, calcium and organic compounds existing naturally in soil.

3.2. Nitrogen

Nitrogen usually exists in septic tank effluent in an organic form, primarily as ammonium.

After ammonified effluent changes its environment from anaerobic conditions, existing in the septic tank, into aerobic conditions, existing in the upper layers of the tile field, the ammonium is being oxidized by nitrifying bacteria into nitrite and nitrate according to following stoichiometry:-

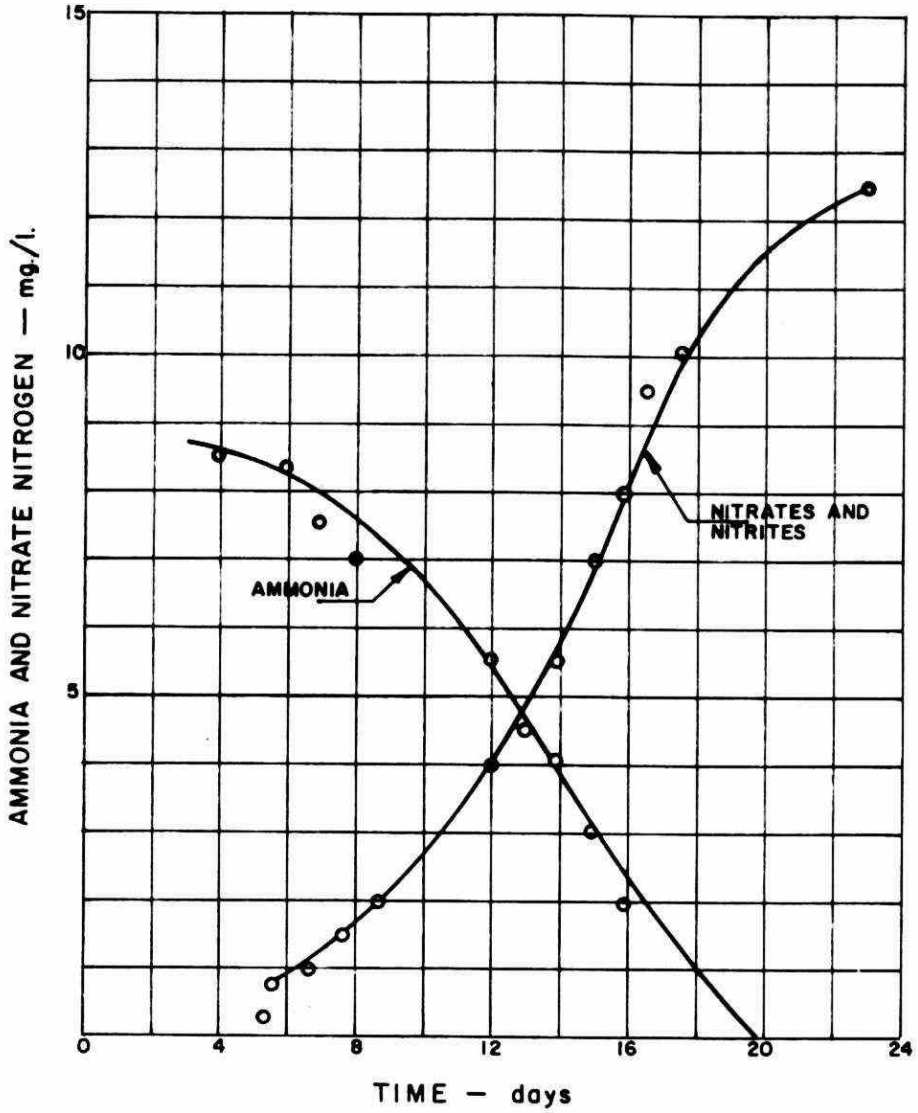
$$NH_4^+ + 3/2\ O_2 \xrightarrow[\text{metabolization}]{\text{Nitrosomonas}} NO_2^- + 2H^+ + H_2O \quad (1)$$

$$NO_2^- + 1/2\ O_2 \xrightarrow[\text{metabolization}]{\text{Nitrobacter}} NO_3^- \quad (2)$$

These reactions furnish energy for the growth of the nitrifying bacteria during which some of the nitrogen is assimilated into bacterial protoplasm and carbon dioxide used as a source of cell carbon (17). By comparison of analyses of waste waters from different sources Preil et al (18) presented following general pattern of nitrogen form in waste water: NH_4 (N)-0 to 50 mg/l; NO_2 (N)-0 mg/l; NO_3 (N)-0 mg/l. An example of the conversion rate of ammonia into nitrates is shown in fig. 1 according to Eckenfelder et al (19). Studies on the mechanism of movement of nitrogen through soil have brought the two following conclusions (17,18)

1. The main factors controlling the movement of nitrogen through soil are Adsorption and Biological action. One of these factors may dominate the other, depending on the soil environment.

2. When the nitrogen is in a form of ammonium ion physical adsorption on soil may be an important mechanism inhibiting the movement of nitrogen. Where the nitrogen is in a form of Nitrates, and in the pH ranges of usual waste waters, practically no inhibition to movement is offered.



NITROGEN RELATIONSHIPS IN THE OXIDATION OF A SEWAGE EFFLUENT

(after W.W. Eckenfelder, Jr. and D.T. O'Connor)

FIG. 1

4. STUDY AREA

4.1. Location of Cottages:

During the period of seven months (June 1 to December 31, 1972) 10 cottages located on Lake Chemong near Bridgenorth and one cottage located on the St. Lawrence River near Gananoque were under intensive study to determine subsurface movement of effluent from private sewage disposal systems towards the receiving body.

The location of the 10 cottages on Lake Chemong is shown on enclosed Fig. 2.

Lake Chemong covers an area of 9.7 sq. miles (about 25 km^2) with an average depth of about 15 feet (4.6m). The total number of cottages adjacent to the lake is about 1200. The site plans of the 11 lots under study showing location of sewage disposal systems, bore holes, wells and lake are given in Appendix I.

The 11 cottages under study have been divided into two groups I and II according to the filtrating abilities of the soil separating the sewage disposal systems from the lake.

The following three cottages located in Bridgenorth on the southeast shore of Lake Chemong comprise group I:

1. 570 Bridgenorth
2. 562 Bridgenorth
3. 589 Bridgenorth

The next eight cottage comprise group II:

4. 1202 Chemong
5. 1283 Chemong
6. 1217 Chemong
7. 1201 Chemong

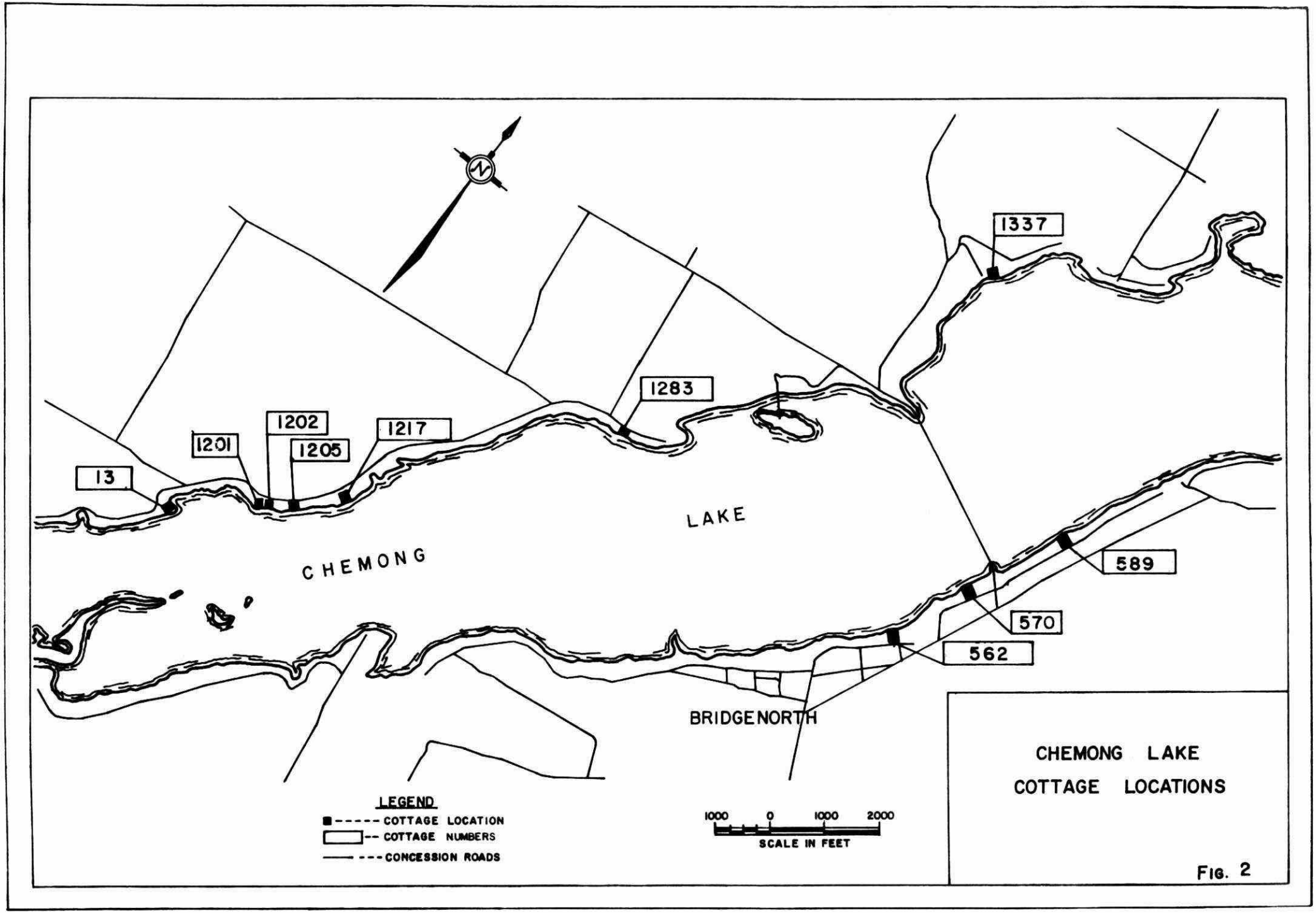

1337
1283
1202
1217
1201
1205
13
LAKE
CHEMONG
589
570
562
BRIDGENORTH
LEGEND
COTTAGE LOCATION
COTTAGE NUMBERS
CONCESSION ROADS
1000 0 1000 2000
SCALE IN FEET
CHEMONG LAKE
COTTAGE LOCATIONS

FIG. 2

8. 1205 Chemong
9. 13 Chemong
10. 1337 Chemong
11. Gananoque

Soil characteristics of samples taken from the study area are given in Appendix II.

4.2. Selection of Lots for Tracer Study

The following five main criteria were taken into consideration when selecting lots:

1. location of lot in relation to the shore line.
2. permanent or temporary use of cottage.
3. location of the drinking water well.
4. distance of the disposal system from the lake.
5. distance of the water table from ground surface.

Only cottages of permanent occupancy located along the lake shore were chosen.

The drinking water wells were located uphill from the septic tank system so to avoid possible contamination of drinking water by the tracers used.

The distances to the lake and the depth to the ground water chosen as great as possible.

Written consents of the cottage owners were obtained for performing studies i.e. for drilling bore holes in the ground, opening of the septic tank, introducing radioactive and dye tracers into the outlet of the septic tank and collecting water samples from bore holes.

5. METHODS AND TECHNIQUES

5.1. Tracing and Tracers

Tracing is a technique of introducing substances to an effluent at one point and detecting them in low concentrations at another point by visual, chemical or radiological means so that the movement of such effluents through soil and ground water can be determined.

Two kinds of tracers were used in this study to observe such movement: 1. two radioactive tracers - Tritium and Radioactive phosphorus (P-32)

2. one dye tracer - Sodium Fluorescein.

The tracers were introduced into the outlets of the chosen septic tanks and then flushed with water into the tile field. (see fig. 1 of Appendix I)

Tritium is a radioactive isotope of Hydrogen (Hydrogen 3), its half-life is 12.5 years, it is a pure β emitter (energy 0.014 MeV max). The low energy of the emitted particle makes for difficulty in counting, but this has been overcome by the use of a liquid scintilation counter.

Radioactive phosphorus (P-32) has a half-life of 14.3 days and a β emission energy of 1.71 MeV (max).

Sodium Fluorescein is an organic dye possessing unique fluorescent properties which allow their detection, by means of fluorometric techniques, at concentrations less than one part per billion (1/μg/l).

The following concentrations of tracers were used:

Tritium	-40 mC_1	in half
P-32	-0.5 mC_1	a gallon
Sodium Fluorescein	-200 g.	of water

The tracers used were carefully selected after consultation with officials of the Ontario Ministry of Health-Radiation Protection Service, the National Health and Welfare Department-Radiation Protection Division and Atomic Energy of Canada-Chalk River Nuclear Laboratories. Safety in use of the tracer, type of radiation, strength and half-life of the isotope were the main criteria for selection of radioactive tracers.

The use of tritium as a tracer of water is discussed in several publications. Generally, most of the investigators consider tritium as a nearly "ideal ground water tracer" (20, 21, 22) and thus meeting basic criteria of a tracer for studying the movement of septic tank effluent through soil.

General opinion exists that tritium is carried with the water at the same velocity as it moves through soil (23) showing low absorptive loss to the porous soil (24) and good detectability in low concentrations. The liquid scintillation counting system permits the detection of tritium in concentrations as low as 0.5 nCi/l with a counting period of 30 minutes (25). Such high sensitivity of the counting methods permits the use of concentrations only 1% of the Maximum Permissible Concentrations (20).

The half-life of tritium is long enough (12.5 years) to permit the use of tritium as a tracer of septic tank effluent which normally takes a few months to travel the distance between the tile field and the lake or river.

Radioactive phosphorus (P-32) is seldom used for tracing underground movement of water. Its half-life is too short (14.3 days) to allow shipment, processing, movement through soil, dilution and counting. Normally about 3 or 4 half-lives

should be allowed for the above action, i.e. about 43 or 57 days. When using radioactive phosphorus during such periods of time, the radioactivity drops to 1/8 or 1/16 of the initial activity respectively and thus higher concentrations of P-32 are required when starting.

Nevertheless, considering the importance of studying the underground movement of phosphates from the septic tanks toward the lakes, radioactive phosphorus (P-32) was used in this study as a tracer. Organization steps were undertaken in order to reduce to a minimum the total time of handling the P-32.

Sodium Fluorescein is suitable as a tracer only in permeable soils that are relatively free from organic matter. Many compounds such as chlorophyll degradation products (e.g. from leaves and grass) which fluoresce, at the same wave length as fluorescein, can affect the fluorometer readings.

The sub-surface movement of radioactive fission products has been under observation by Chalk River Nuclear Laboratories since 1954 and results were published in several papers (26-31).

The results obtained by the CRNL were based on the underground movement of relatively large amounts of radioactive products (Hundreds of thousands times higher than amounts used in this study). Such radioactive products have been added continuously for years to large radioactive waste disposal areas which became the primary sources for the underground movement of radioactive products. In these investigations, tracers were added only once to each sewage disposal system under study.

In his paper on Movement of Radioactive Waste Through Soil (29) Parsons described a small deposit pit of radioactive liquid where about 1,000 to 1,500 curies of mixed fission

products were discharged. In another experimental study carried out by Merritt (27) in order to determine the direction and effective velocity of ground water flow, a mixture of 1,500mCi of tritium, 2mCi of radioactive sulfur,S35 and 25g of fluorescein was used. The distance of the detected tritium from its original source was about 15 to 24 feet (4,57m to 7,32m) i.e. of the same order as the distances between the tile fields and the drilled holes in which tritium was detected and reported in this study.

The rate of flow of tritium observed by Merritt, in soil composed mostly of sand, was about 7 inches (0,18m) per day, while other tracers moved slower (radioactive sulfur (S 35) moved at a rate of 6.7 inches (0,17m) per day and fluorescein at about 5 inches(0,13m) per day. The flow rates of tritium determined in Parsons' studies were 4.5 inches (0,11m) and 12 inches (0,31m) per day in soils of permeability factors of 6.1 feet (1,85m) per day and 15 feet (4,56m) per day respectively (26). In a later study, Parsons determined the flow rate of tritium in the same soil as 1.5 feet (0,46m) to 2 feet (0,61m) per day (31).

Some preliminary studies on movement of tracers through soil carried out in the Whitby Experimental Station (Ministry of the Environment) have shown that fluorescein moves with a velocity of about 5 feet per hour (1.5 m/h) through sand of a grain size D_{10}=0.24 mm and uniformity coefficent Cu = 3.9, while the fluorescein did not move at all through natural undisturbed soil containg 49 % of Clay, 45% of silt and

6% of sand (Whitby lot). Phosphorus introduced into the ground in a form of KH_2PO_4 was detected in the same soil in distances not more than 2 feet. Tritium reached, in the same undisturbed soil, a bore hole drilled at a distance of 150 feet (47.7 m), i.e. a velocity of about 1 foot per day (0.3 m/day). The tritium was found in the ground water of some test holes as long as twelve months after it was injected into the first test hole (32).

Extensive field and laboratory tracer studies have been conducted by Moser et al of the University of Munich, Germany (33-39). Radioactive tracers such as tritium, phosphorus (P-32) and other dye tracers like fluorescein and sulforhodamine G were used for studying the velocity and direction of ground water movement. In their studies the authors found again that tritium moves through soil faster than other radioactive and dye tracers. Some correlations were found between the flow rate of water in soil and the permeability of the soil (35). Also the humidity of the soil was determined by using tracers (34). The authors worked out precise methods for detecting tritium in very low concentrations. They also described a new fluorometer for measuring the concentrations of fluorescent dyes (37).

5.2. Location and Arrangement of Bore Holes

The bore holes were drilled by hand or by power auger and so located as to intercept the septic tank effluent in its travel in the ground between the tile field and the lake or river. Additional control holes were similarly drilled and located in such points where it was likely that no septic tank effluent could reach them (Appendix I).

Before drilling or digging the test holes, the area surrounding the hole within a radius of about 5 feet, was carefully cleaned of stones, leaves, twigs, grass and different kinds of visible contaminants, e.g. manure, feces dead birds or animals, etc.

3" diameter holes were drilled to a depth of not less than 18" below the groundwater level. The holes were cased with 3" unperforated pipe. The lower end of each pipe had three or four slits cut, each ¼" wide and about 18 inches in length to facilitate entry of groundwater to the cased bore hole (Fig.3).

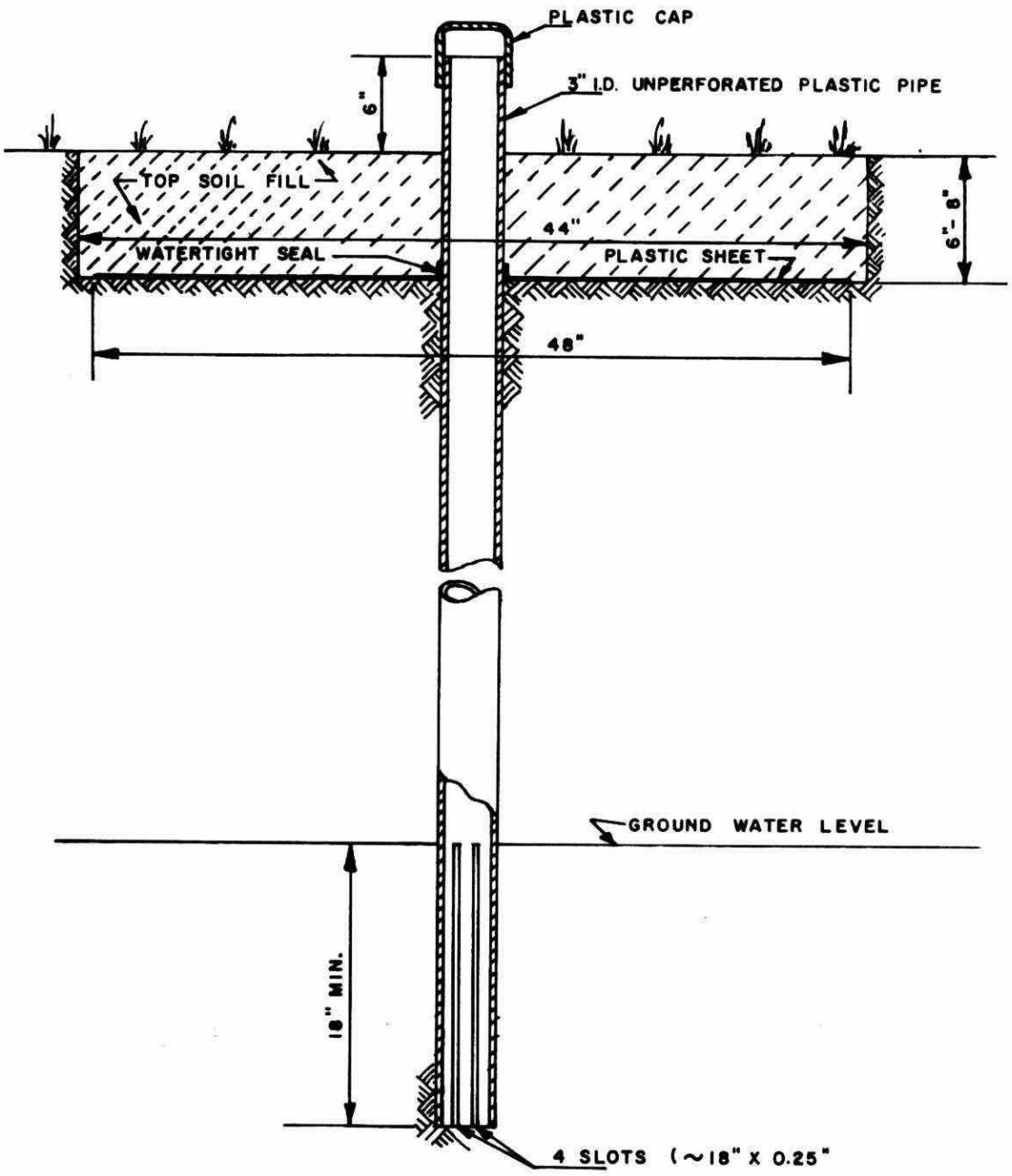
In order to prevent entry of surface water into the hole, the area surrounding the bore hole was covered with a water proof plastic sheet, stuck tightly to the pipe. The protecting sheet, approximately 4 feet in diameter, was laid at a depth of 6 to 8 inches below the ground surface and covered by clean soil. Thus, grass could grow above the sheet.

5.3. Sampling and Analysis

Soil samples were taken from each drilled bore hole, at a depth close to the water table, and sent to the Soil Laboratory for testing.

Before starting to take background samples, the water inside the bore holes was chlorinated and subsequently pumped out several times. At the same time, the inside surface of the casing pipe was disinfected with the chlorinated water. Water samples from bore holes were taken throughout the test period by using metallic ladles sterilized before each sampling.

The water samples were delivered to laboratories as follows:



CASING AND PROTECTION OF BORE HOLES

FIG. 3

1. Public Health Laboratory in Peterborough for bacteriological tests of samples from lots located on Lake Chemong.
2. Public Health Laboratory in Kingston for bacteriological tests of samples from the lot located in Gananoque.
3. Ministry of the Environment Laboratory, Resources Road for chemical analysis of all samples.
4. Ministry of Health, Radiation Protection Laboratory, Christie Street for tritium and radioactive phosphorus tests.

6. RESULTS

6.1. General

During the testing period, 3513 water samples were collected from forty-one cased and protected test holes, and tested for bacteria, chemicals and for radioactivity.

The laboratory results which show the concentrations of the tracers and the degree of bacteriological and chemical contamination of the ground water in the bore holes, are presented in table 1 to 5 of Appendix III.

Where tritium was detected in the bore holes, the radioactivity of tritium and that of P-32 were plotted versus time on graphs 1 to 10 of Appendix IV.

6.2. Group I Sewage Disposal Systems

It turned out that the sewage disposal systems of the chosen Group I were built on imported fill material containing mostly silty sand and boulders. Such a filtrating medium containing channels and voids creates favourable conditions for the septic tank effluent to reach the bore holes and the lake.

It seems quite clear why high bacteria counts, high tracer concentrations and high phosphate levels were detected in groundwater samples collected from bore holes drilled in these lots. (See Appendix III).

High bacteria counts: more than 8,000,000/100 ml of total coliforms and up to 4,680,000/100ml of faecal coliforms were found in some of the bore holes. Also high radioactivity

of tritium (up to 550 nCi/l) high concentrations of phosphorus (14.5 mg/l as P) and high concentration of of fluorescein (26.9 mg/l) were found.

In bore hole No.5 of lot 562 located at a distance of about 22' from the tile field (and only about 5' from the lake), the average concentration of phosphorus was 11.6 mg/l i.e. about the same concentration as observed normally in septic tank effluent. Very high bacteria counts were also found in holes No. 2 and 4, of the same lot. The total coliform counts were: $8,000,000^{+}$/100 ml in each of the holes (No.2 and No.4) and 4,682,000 faecal coliforms per 100 ml in hole No. 2 and 2,372,000 faecal coliforms per 100 ml in hole No.4.

It became evident that the sewage disposal system of lot 562 located in a distance of about 27' from the lake shore and built on loose fill material, was contributing to lake pollution.

High radioactivity of tritium was found in hole No. 1 located in a distance of 6'from the tile field of lot 570. Even the so-called "control hole" of lot 570 which was unfortunately located within a polluted area (location of hole shown on site plan, Appendix I) showed 190,000 of total coliform and 6,000 of faecal coliform counts per 100 ml of water. Despite the distance of 53' 10" existing between the lake and tile field of cottage 570, the sewage disposal system seems to pollute the lake.

The bore holes of the third cottage of the same group (lot 589) showed also relatively high bacterial pollution of the groundwater (see Appendix III). Hole No. 3 showed a

contamination with total coliforms of 116,600 counts per 100 ml but only 100 faecal coliform counts per 100 ml. Also, the "control hole" (No. 4) in lot 589 located uphill from the tile field showed high contamination with bacteria (90,600 total coliforms and 36,800 faecal coliforms per 100 ml) effluent probably coming from the sewage disposal systems located nearby at a higher elevation tile field through channels between stones and boulders.

Tritium was detected in holes No. 1 and No. 3 of lot 589 reaching a relatively high concentration in hole No. 1 (525 nCi/l). (See graph of Appendix IV). However, the time taken by the tritium to reach hole No. 1 was as long as 62 days, and that may be the reason why only 300 faecal coliforms per 100 ml have survived such a relatively long period. The time taken by the tritium to reach hole No. 3 of 589 was 69 days and in this case only 100 faecal coliforms per 100 ml have survived. It seems then, as one would expect, that septic tank systems which allow rapid passage of effluent through filtering media are not effective in removing bacteria and phosphates, e.g. the septic tank effluent reached hole No. 1 of lot 570 after 9 days, bringing into the hole as much as 780,000 faecal coliforms in every 100 ml of effluent. The concentration of phosphorus in the same hole (No. 1) was, however, only 1.47 mg/l; the concentration of fluorescein, 26.9 µg/l.

Radioactive phosphorus (P-32) was detected in only one of the test holes which was drilled very close to or within the tile field area (hole No. 3 of lot 562). The radioactivity of P-32 in that hole was as high as 675 cpm/100 ml while the radioactivity of P-32 in water samples taken from other test

holes was almost the same as in the background samples, i.e., about 5 cpm/100 ml. Also, very high concentrations of tritium (1910 nCi/l) and that of fluorescein (1157 µg/l) were detected in that particular hole.

Generally, it can be concluded that Group I sewage disposal systems built in fill material which contains stones and boulders, contribute, in some degree, to polluting Lake Chemong. It seems reasonable to avoid, in future, the use of such fill material containing stones and boulders for sewage systems.

6.3. Group II Sewage Disposal Systems

Results obtained from studies on the septic tank systems of the second group of 7 cottages (see Appendix III) located on the north-west shore of Lake Chemong and of one cottage in Gananoque, have shown better filtering abilities of the soil systems than those of group one and in most cases almost a complete removal of faecal coliforms and phosphates from the septic tank effluent.

It seems reasonable to assume that these good results are due to adequate soil properties between the tile fields and the bore holes. The characteristics of the soil from all lots are shown in Appendix II. In most of the lots studied (except Lot 1201) the soil contained more than 40% silt and clay (jointly).

The concentration of faecal coliforms in all but one of the bore holes (hole No. 1 in lot 1202) was very low and no faecal coliforms were detected in the water samples taken from test holes drilled in lots 1283 and 1205.

Also, the concentration of phosphorus in the water samples tested was low (see tables 3 to 6, Appendix III).

The distances between the tile fields and the lake shore, the depth of water table, as well as the soil properties were found to be determining factors in the removal of coliform bacteria and nutrients from the effluent. In all of the cases studied in Group II, the distances from tile fields and the lake were more than 50 feet.

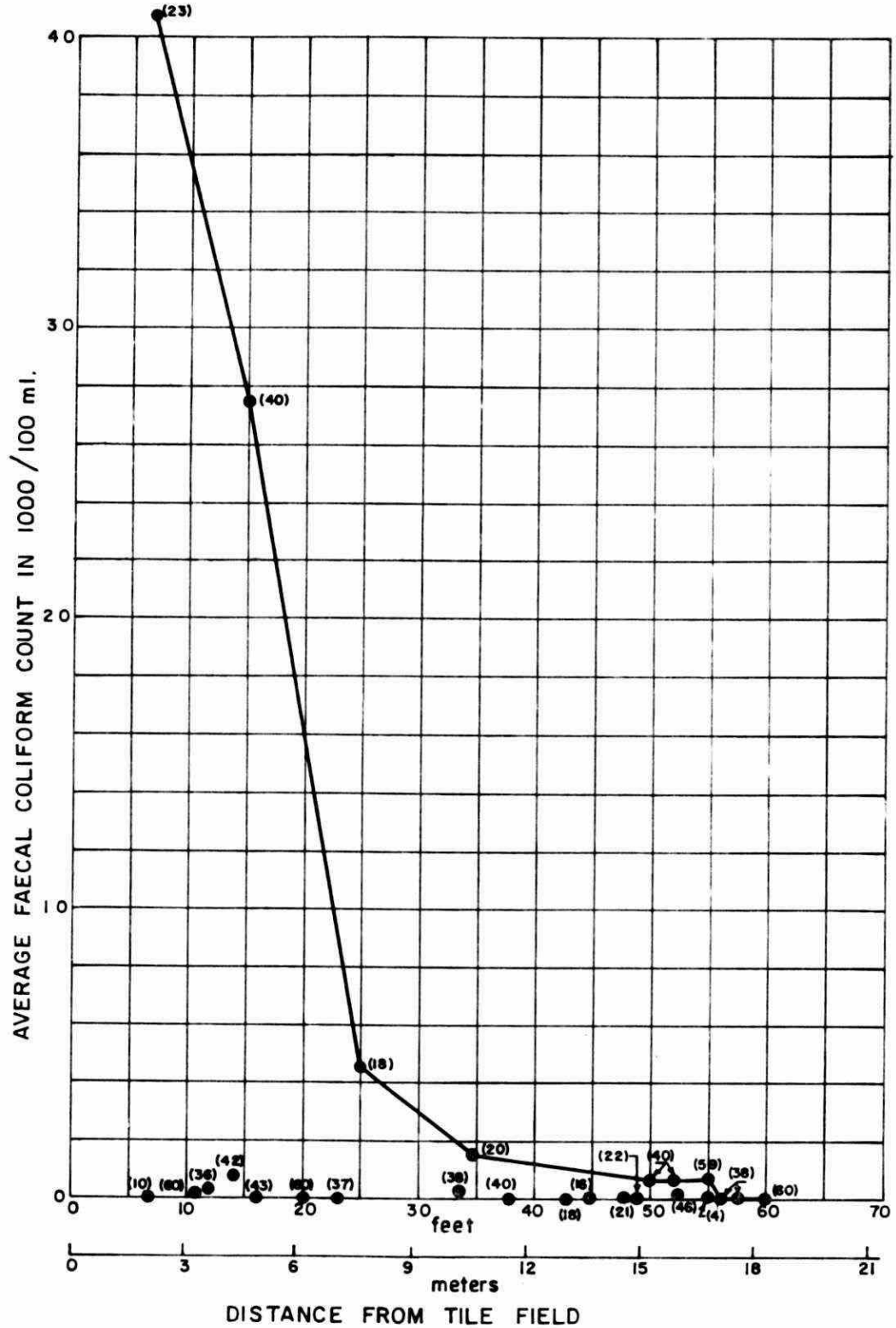
Figure 4 shows the effect of the distances from tile field on the average faecal coliform counts in the water samples tested.

6.4. Group I and II Combined Results

It was observed that the coliform counts in water samples decrease with the distance of test hole from tile field or with the time the septic tank effluent takes to travel to the test hole.

On the average, within a distance of about 25 feet (7.5 m) from the tile field the average number of faecal coliforms is reduced from about 8 million in septic tank effluent to about 4,000 organisms per 100 ml in ground water.

In bore holes located at distances greater than 55 feet from the tile field, no faecal coliforms were detected. It can be assumed that if the time of travel through the unsaturated and saturated zones of the ground is long enough, the bacteria can be expected to die out. It is generally accepted that the survival time of faecal bacteria moving through soil depends on moisture content, acidity, and alkalinity of the soil, chemical composition of the transporting effluent, temperature



Number of samples tested are shown in brackets. (group II)

THE EFFECT OF DISTANCE FROM TILE FIELD ON AVERAGE FAECAL COLIFORM COUNTS IN GROUND WATER

FIG. 4

of the environment and antagonistic predatory or beneficial effects of other microorganisms in soil and effluent. Survival times of some types of faecal bacteria in different underground environments are given in Table 3.

Table 3

No.	Bacteria	Environment	Survival Time	Source
1	Escherichia coli	In feces covered with garden soil or sand at 20°C - 37°C	36-48 days 10-20 days	40 40
2	Streptococci	In soil	35-63 days	41
3	Salmonella	In lower layers of soil	70 days	42
4	Shigella flexneri, Shigella Sonnei	In water at 19-24°C	3-9 days	43 44,45
5	Salmonella typhi	In soil	74 days 70-80 days	46

The use of tritium for tracing the movement of septic tank effluent facilitates the determination of the travel time and consequently the velocity of the effluent between bore holes, tile fields, and lake.

The dates the tritium was introduced into the outlet of the septic tank and the dates of the breakthrough of the tracer are shown on the graphs of Appendix IV. The tracer travel distances were considered, roughly, to be equal to the distances between the edge of the tile field and test hole. However, the exact point the tracer leaves the tile and enters the ground is not known.

The following approximate velocities of the subsurface movement of tritium were determined from the study:-

Velocities of Subsurface Movement of Tritium

Table 4

Cottage	No. of Hole	Velocity	
Group I		ft/day	m/day
Cottage 570	1	0.7	0.21
" "	2	0.5	0.15
" "	3	2.0	0.60
" 589	1	0.2	0.06
" "	3	0.5	0.15
Group II			
Cottage 1202	1	0.06	0.02
Cottage 1283	1	0.33	0.10
Cottage in Gananoque	3	0.33	0.10

Assuming the maxiumum velocity of movement of the septic tank effluent through undisturbed soil (Group II) is not higher than the velocity observed in subsurface movement of tritium in the same environment (0.33 feet per day), the time of about 165 days required for travelling a distance of 55 feet is much longer than the survival time of faecal bacteria in soil and water.

6.5. Phosphates and Nitrates in Ground Water Samples Studied

The average concentration of phosphates and nitrates observed in water samples are presented in Tables of Appendix III. The numbers of water samples tested are also given.

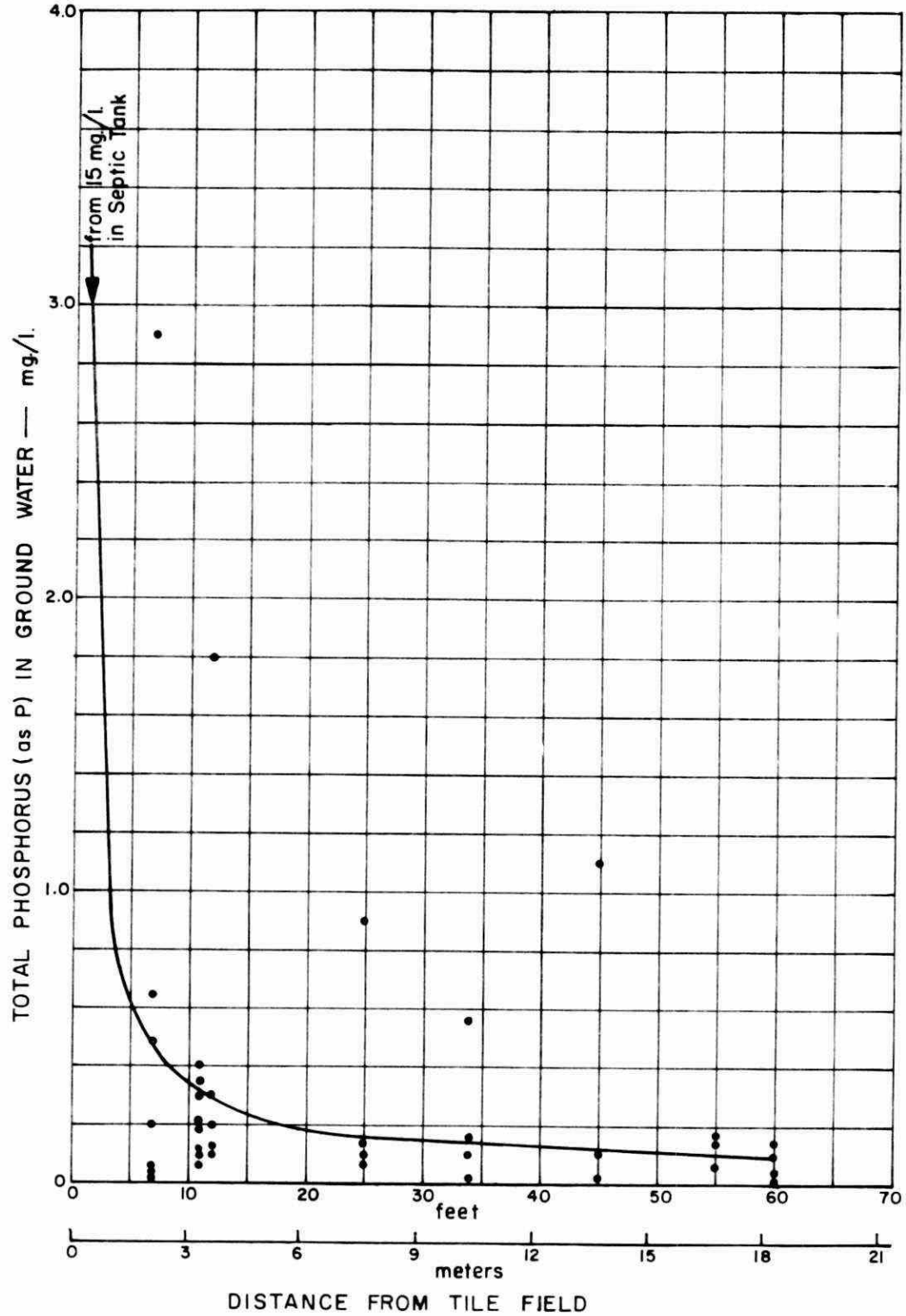
The concentration of phosphates in water samples appeared to drop with the distance of bore holes from tile field and with the increase of silt and clay content in the soil.

The concentration of phosphorus in water samples taken from holes drilled directly in the tile field area of Lot 562 or very close to the tile field was 11.8mg/l (as P). In test hole No. 5 of the same lot the concentration of phosphorus in water samples was also very high (11.6 mg/l) probably because a direct connection (channel) between bore hole and tile field could exist. The usual concentration of phosphorus in septic tank effluent from domestic sewage is about 15 mg/l to 20 mg/l (as P).

A decrease in phosphorus concentration with distance from tile field was observed in all cases studied except for the lots of the first group where soil with boulders as fill material was used.

Even in the above cases (group I cottages) some time was required for the effluent to travel the distance to the bore holes and thus,a decrease in phosphate concentration was observed in water samples from some bore holes.

In undisturbed natural soil containing 80 to 100% of silt, clay, and fine sand (jointly), a decrease in concentration of phosphorus from 15 mg/l (in septic tank effluent) to 0.1 mg/l in a distance of 60 feet (18.3 m) from the tile field was observed. Ninety-eight percent of the decrease in concentration took place within the first 10 feet (3.05 m) from the tile field, probably mostly within the unsaturated zone. The effect of distance from tile field on concentration of phosphorus in ground water is shown in Fig. 5.



Soil containing from 80% to 100% of silt and clay size particles.
Silt — (0.002 – 0.075 mm.)
Clay — (< 0.002 mm.)

THE EFFECT OF DISTANCE FROM TILE FIELD ON PHOSPHORUS CONCENTRATION IN GROUND WATER

FIG. 5

7. DISCUSSION

7.1. Movement and Detectability of Tritium in the Ground Water

Tritium was detected in only 10 of the 41 test holes studied. The reason for undetectability of tritium in the rest of the holes can be attributed to the complex pattern of the subsurface movement of the tracer and to the high dilution of the tritium in the ground water.

In holes drilled in the imported fill material (group 1 cottages) the tritium was detected in almost every second hole (13 holes tested, 7 holes with tritium) with an average concentration of tritium of 192 nCi/l. The velocity of movement was between 0.2 to 2.0 ft/day (0.06 to 0.60 m/day). In holes drilled in uniform undisturbed soil (group II cottages) tritium was detected in almost every tenth hole (28 holes tested, 3 holes with tritium) with an average concentration of tritium of only 27 nCi/l.

The velocity of movement in soil containing more than 93% of very fine material (clay, silt and fine sand) was 0.33 ft/day (0.10 m/day). It can be concluded from the above observations that the pattern of underground movement of tritium was different in the two different soils.

In imported fill material containing stones and boulders, the subsurface movement of tritium is faster and can be likened to a multiflume flow covering a larger area and reaching even the furthest bore holes.

In uniform undisturbed soil, the tritium seems to move more slowly and in narrow tongue-like flumes reaching only the nearby bore holes.

7.2. Advantages of the Use of Tritium

The detection of tritium at different points in the ground water facilitated the determination of the speed of ground water movement and the dilution ratio of the tracers in the ground water.

7.3. Movement and Detectability of radioactive phosphorus (P-32) in ground water

Results of this study have shown that radioactive phosphorus (P-32) was not detected in the bore holes despite the fact that tritium was detected.

Only in one of the bore holes probably drilled in the tile field area or very close to the tile field (hole No.3 of lot 562) a relatively high gross beta radioactivity was detected (675 cpm/100 ml).

Two different reasons could account for the undetectability of the radioactive phosphorus (P-32) in most of the bore holes:

1. The radioactive phosphorus was fixed in the soil and did not reach the bore holes.

or 2. The high dilution of the phosphorus (P-32) in the ground water and the natural decay of radioactivity of the P-32 reduced the radioactivity to a level lower than the detection ability of the counting equipment which is considered to be about 20 cpm/100 ml.

By using simple calculations, an attempt was made to find out whether the high dilution of the P-32 in the ground

water and the natural decay of the P-32 could cause a drop in radioactivity of the P-32 below 20 cpm/100 ml i.e., below detectability by the laboratory equipment.*

The calculation was based on an assumption that no detention of the P-32 in the soil took place and thus the degree of dilution in the ground water of both the tracers used (i.e. of the tritium and of the P-32) was the same.

The natural decay of tritium (which has a half life of 12.6 years) was not taken into account in the calculation.

Results obtained from water samples collected from the following bore holes were used in the calculations:

a. Hole No. 1 in lot 570 where relatively high radioactivity of tritium was observed but the radioactivity of P-32 (see graph No.1 of Appendix IV) was not higher than that of the background samples. In samples from hole No. 1, two peaks in radioactivity of tritium were observed: one of 145 nCi/l on July 7, i.e., 24 days after introducing the tracers and one of 210 nCi/l on August 1, i.e., 47 days after the tracers were introduced.

b. Hole No. 3 in lot 562 where the peak in radioactivity of tritium observed on July 15, i.e. three days after introducing the tracers, was

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*The minimum detectable radioactivity of P-32 (20 cpm/100 ml) used in this calculation is about 4 times higher than the actual detectability of the equipment used.

1,900 nCi/l (graph 4, Appendix IV).

c. Hole No. 5 in lot 562 where peak in radioactivity of tritium was observed on August 25, i.e., 44 days after introducing the tracers (see graph 5 of Appendix IV).

The radioactivity of the concentrated tracers before they were introduced into the outlets of the septic tanks was:

tritium: 40 mCi in half a gallon of water

P-32: 0.5 mCi in half a gallon of water

If the radioactivity of the tritium in the ground water is X nCi/l, the radioactivity P-32 would be $\frac{0.5\ X}{40}$ nCi/l.

The radioactivity of P-32 in ground water samples was reported by the Radiation Protection Laboratory in cpm/100 ml (cpm = counts per minute) and that of tritium in nCi/l. As the rate of radioactive disintegration of one nanocurie (nCi) is 37 disintegrations per second and the counting efficiency of the equipment used for counting P-32 radiation is 55%, the following conversion factor between the two different measurements could be used:

$1\ \text{cpm} = 82 \times 10^{-5}$ nCi or 1 nCi/l = 122 cpm/100 ml

P-32 disintegrates by a decay factor D(y), $D(y) < 1$, y = number of days, thus the P-32 radioactivity after y days would be:

$$X\ D(y) \times \frac{0.5}{40}\ \text{nCi/l} =$$

$$= \frac{XD(y)}{80} \times \frac{10^5}{82} \times \frac{1}{10}\ \text{cpm/100 ml} =$$

$$= \underline{1.524\ X\ D(y)\ \text{cpm/100 ml}}$$

Table No. 5 presents calculated values of P-32 radioactivity which would be detectable if the P-32 moved through the soil at the same rate as the tritium.

Table 5

Hole No.	No. of Days y	D(y)	Radioactivity of tritium nC/l X	Calculated P-32 radio-activity cpm/100 ml
1, cottage 570	24	1/3.2	145	69.1
1. cottage 570	47	1/9.76	210	32.8
5 cottage 562	44	1/8.44	220	39.8
3 cottage 562	3	1/1.16	1,900	2500

Values of P-32 radioactivity obtained by calculation were in excess of the minimum detectable P-32 radioactivity which is 20cpm/100 ml. Hole No. 3 of lot #562 is the only hole where P-32 was detected. The actual radioactivity of the P-32 was only 675 cpm/100 ml while the calculated radioactivity of P-32 in that hole is 2500 cpm/100 ml. What this means is that part of the P-32 was detained in the soil.

An attempt was also made to calculate the initial concentration of the P-32 to be used in future, so as to still have a detectable concentration of the tracer (>20 cpm/100 ml) after two months of dilution and radioactive decay.

The same assumption was made that the dilution of the P-32 in the ground water after two months is the same as the observed dilution of tritium, and that no detention of the phosphorus in the ground takes place.

During a period of two months, the radioactivity of the P-32 will drop to 1/18.33 of its initial intensity, therefore, the required initial concentration will be:

$$20 \text{ cpm/100 ml} \times 18.33 \times 10^{6} \times 82 \times 10^{-11} \text{ mCi/cpm} \times 4550/\text{ml imp. gal}$$

(detectability) (natural decay) (dilution factor) (conversion factor)

$$= \underline{13.7 \text{ mCi/imp.gal}}$$

The use of an initial concentration of P-32 of about 15.0 mCi/imp. gallon seems to be enough for the tracer to be detectable in ground water samples after two months of dilution and radioactive decay if no retention in soil takes place.

8. CONCLUSIONS

8.1 Effect of Distances of Private Sewage Disposal Systems from Receiving Water on Sewage Treatment Efficiency.

a. Phosphorus Removal

The simultaneous use of two radioactive tracers, Tritium and Radioactive Phosphorus (P-32) for tracing the underground movement of septic tank effluent has shown that only Tritium was detected in the ground water. No P-32 was detected. Assuming the dilution of the P-32 in the ground water to be the same as that of the Tritium, and taking into account the natural radioactive decay of the P-32, it was shown, by simple calculations, that the P-32 should have been detected in the ground water if no detention in the soil took place. It seems the P-32 was fixed in the soil. Calculations based on experimental results obtained in this study have shown that higher concentrations of P-32 (more than 15 mCi/gal) should be used in future similar field studies in order to determine without question whether or not (P-32) phosphorus is fixed in soil*.

Chemical analyses of ground water samples taken from test holes which were drilled at different distances from the tile field show a significant decrease in concentration of phosphorus within the first 10 feet from the

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* An increase to 30 mCi/gal of radioactive phosphorus (P-32) was used in the 1973 tracer study but no P-32 was detected in the ground water samples, while tritium was detected (M.B.).

tile field. The drop in concentration was about 98%, i.e. from 15 mg/l (as P) in septic tank effluent to 0.3 mg/l in the test holes.

At a distance of 60 feet from the tile field the average concentration of phosphorus was only 0.1 mg/l, i.e. about the same average concentration as usually found in non-contaminated ground water in the Chemong Lake area and 10 times less than the concentration of phosphorus recommended by the Canada-United States Agreement on Great Lakes Water Quality, as an objective for effluent from wastewater treatment plants. (47).

b. Nitrates Removal

Scattered results of concentrations of nitrates in ground water do not provide sufficient information on movement of nitrates through soil.

c. Removal of Coliform Organisms

Imported fill material, containing stones and boulders, which was used for sewage disposal at the investigated I group of cottages (located on the south-east shore of Lake Chemong), has created favourable conditions for the sewage to reach easily the ground water and the lake and contaminate it with high amounts of coliform bacteria.

The distances of up to 53 feet (~16 m) between the tile field, and lake shore as well as the depth of 5 to 7 feet (1.5 to 2.1 m) to the ground water, applied in the above sewage disposal systems, seems to be inadequate to protect the lake from contamination with bacteria when such imported fill material is used.

When uniform undisturbed soil containing more than about 40% of silt and clay (jointly) was used for disposal of sewage (II group of cottages), no faecal coliform were detected in ground water taken from test holes located at distances of 55 feet (16.5 m) or more from tile field.

8.2 Effect of Ground Water Depth on Sewage Treatment Efficiency.

The effect of ground water depth on treatment efficiency and classification methods were not determined and will be given further consideration in part II study 1973. Special technique is required for intercepting the septic tank effluent inside the soil strata between the bottom of the absorption trench of the tile field and the water table.

8.3 Soil Type.

The complexity of the soil cations-phosphorus interactions in different soil conditions suggests the necessity of intensive experimental and theoretical studies in this field. Chemical and bacteriological analyses of soil samples taken from different points in the disposal system, are scheduled for part II-1973 study.

8.4 Effluent Travel Time.

The maximum velocities of subsurface movement of tritium were found to be:

a. 2.0 ft/day (0.6 m/day) in imported fill material containing stones and boulders

and

b. 0.33 ft/day (0.1 m/day) in undisturbed uniform soil containing about 90% of fine material (clay, silt and

fine sand). Assuming the distance of the sewage disposal system from water body is not shorter than 50 feet (~ 15.00 m) (as usually recommended), the effluent travel time will be not less than 25 days in fill material and 150 days in undisturbed uniform soil.

8.5 Tracers

a. Tritium proved to be a very good radioisotope for tracing underground movement of septic tank effluent.

The pattern of flow of tritium in fill material was observed to be rather like a multiflume covering a larger area whereas in undisturbed uniform soil, the tritium travelled along narrow tongue-like singular flumes.

b. Radioactive phosphorus (P-32) was not detected in the ground water and is not as suitable for tracing underground movement of septic tank efflunet as tritium. The tracer (P-32) proved, however, to a great extent, the phenomenon of detention of phosphorus by soil.

c. In undisturbed soil, fluroescein was not detected in the ground water in concentrations higher than those in the background samples. Fluorescein cannot be recommended for tracing underground movement of septic tank effluent in soil, it can be used only for tracing the movement of septic tank effluent in coarse sand.

8.6 Future Work

The results are considered to be encouraging enough to recommend continuation of the program at least into 1974 and 1975.

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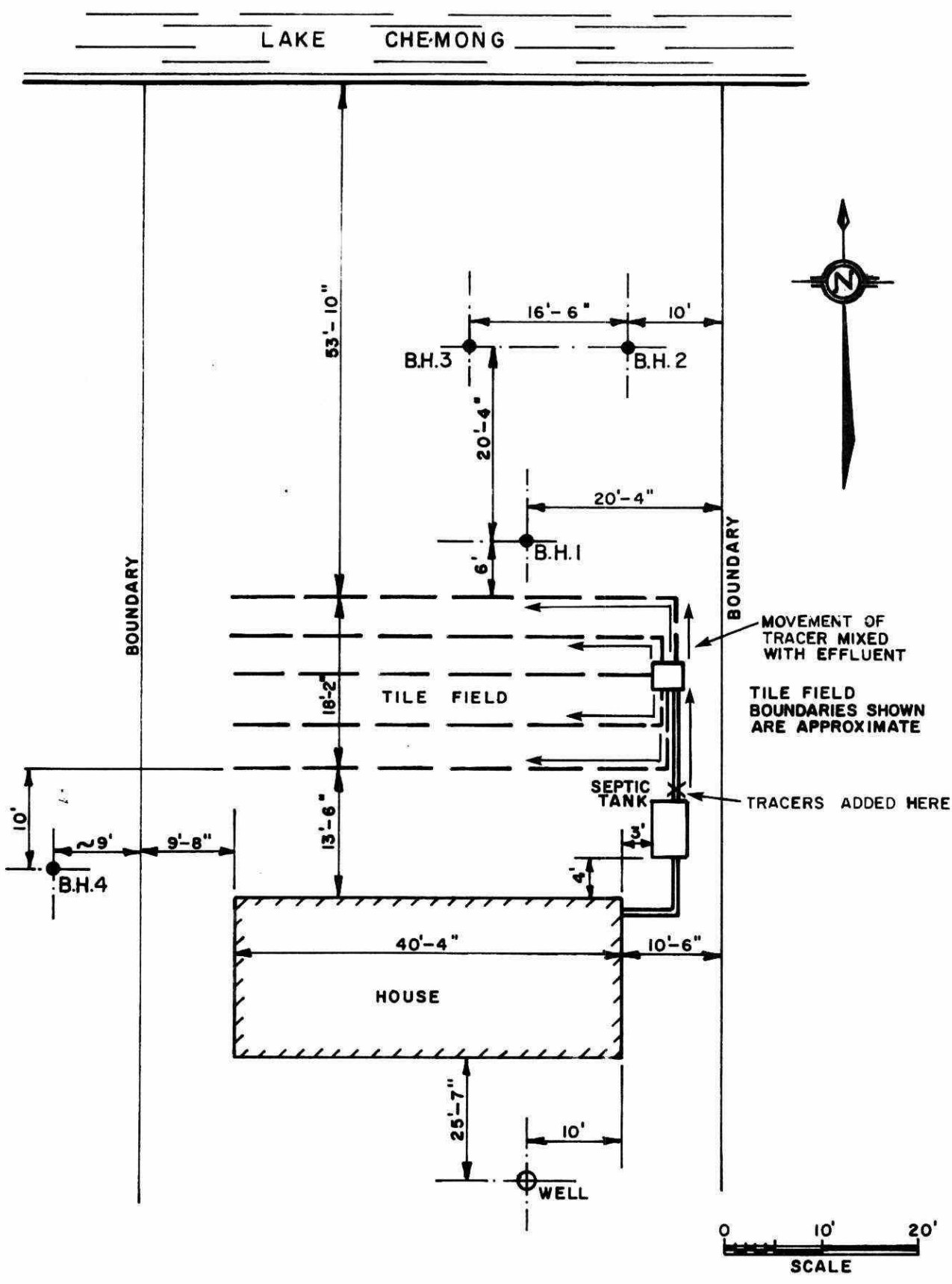
APPENDIX I

TRACER STUDY

SITE PLANS

11 Figures

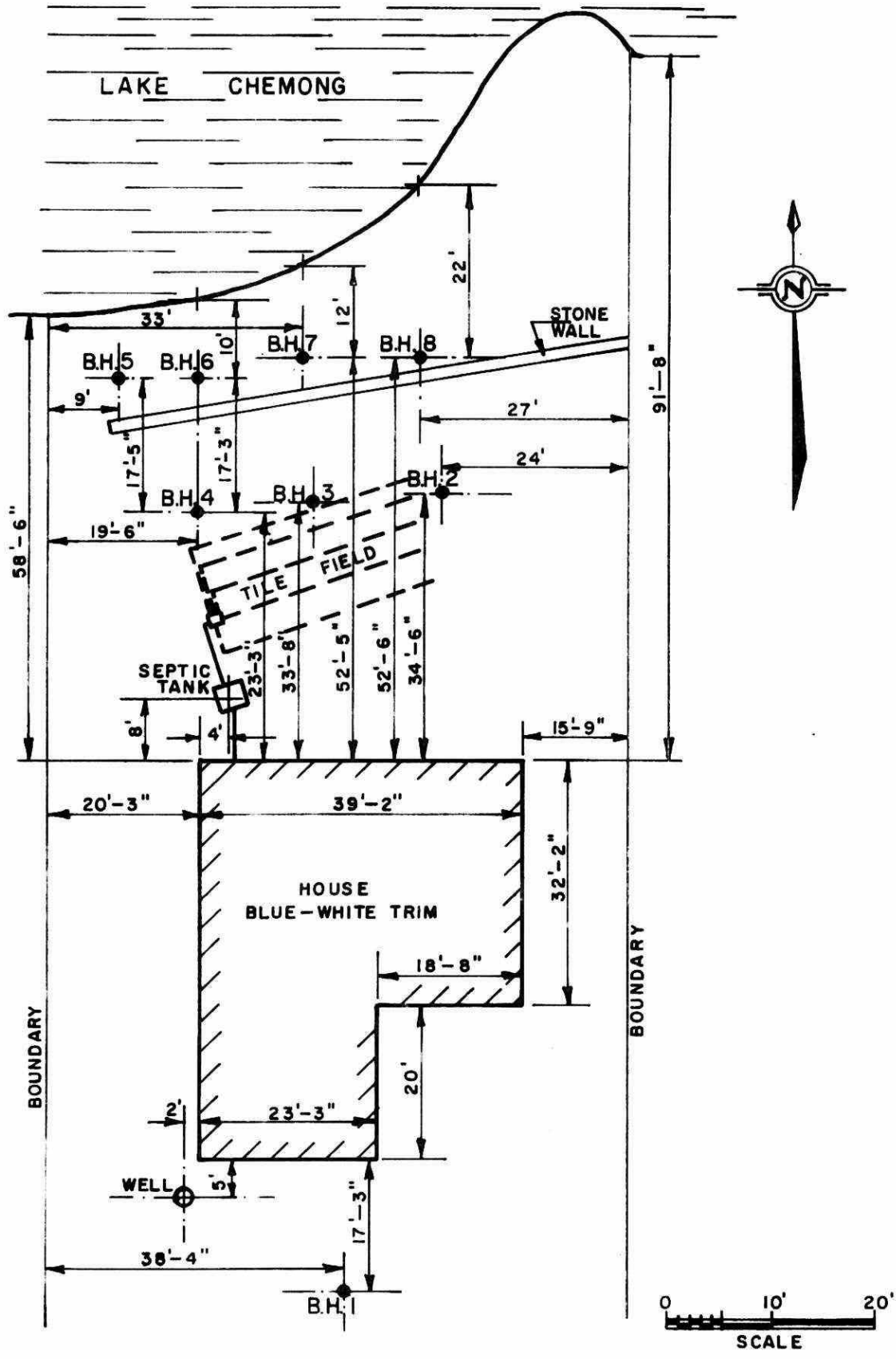


B.H. ● — BOREHOLE

BORE HOLE	DEPTH IN FEET
1	4.42
2	4.00
3	4.58
4	6.83

TRACER STUDY SITE PLAN
EST. 570 BRIDGENORTH

FIG. 1

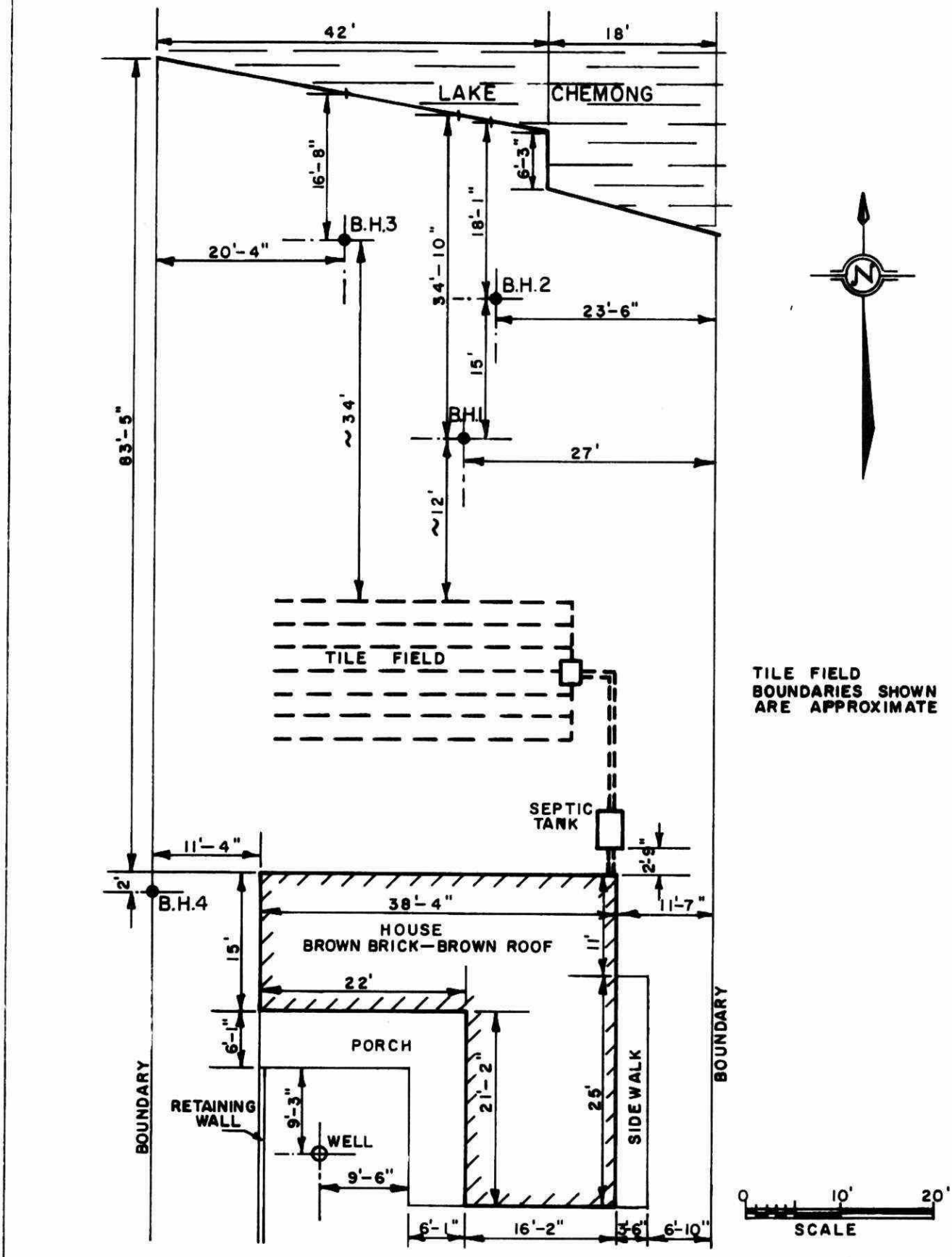


B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	8.0
2	5.5
3	7.0
4	6.5
5	6.0
6	5.5
7	4.5
8	5.5

TRACER STUDY SITE PLAN
EST. 562 BRIDGENORTH

FIG. 2

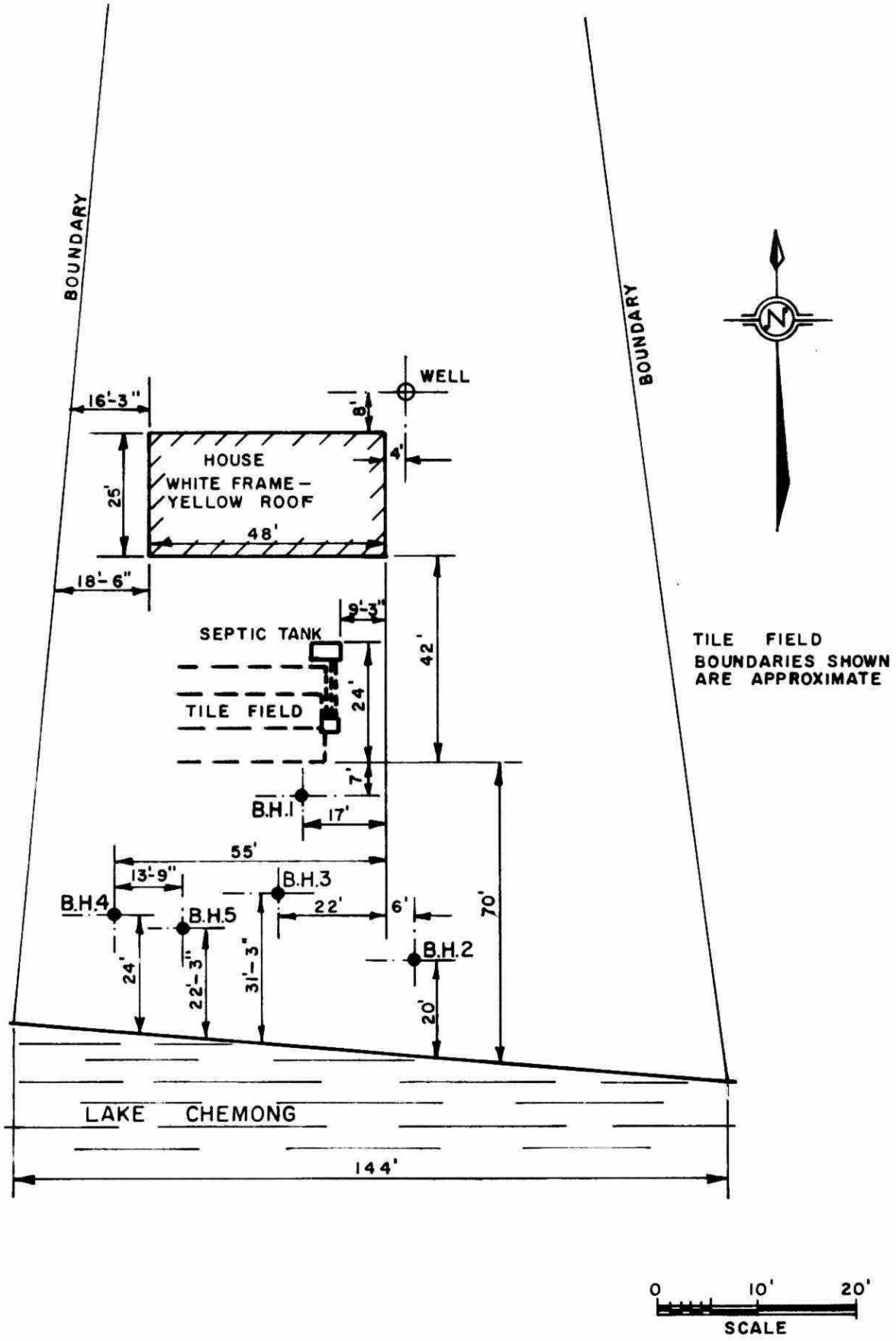


B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	4.0
2	5.0
3	5.4
4	5.5

TRACER STUDY SITE PLAN
EST. 589 BRIDGENORTH

FIG. 3

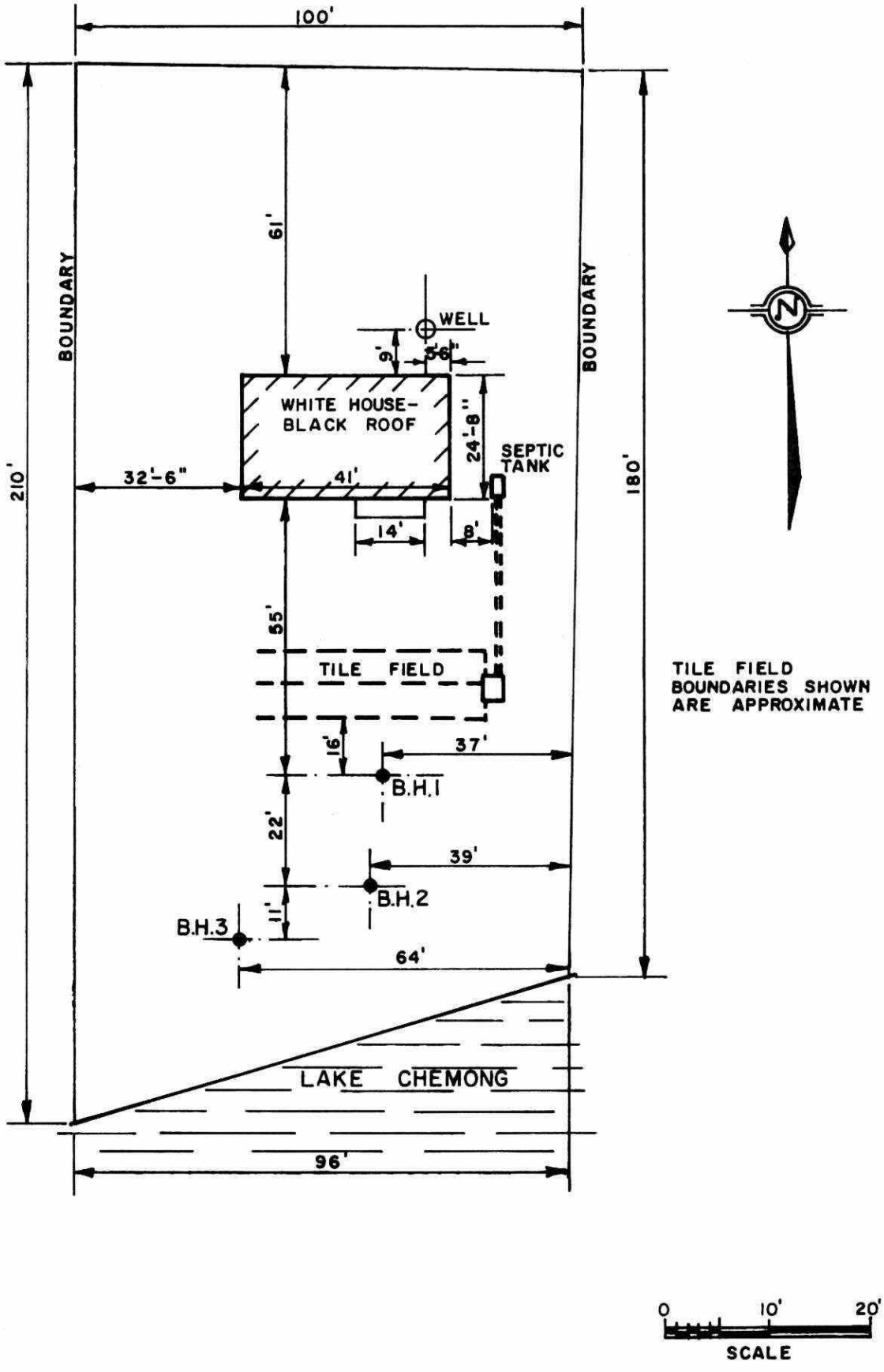


B.H. ● —BOREHOLE

BORE HOLE	DEPTH IN FEET
1	4.83
2	3.5
3	3.08
4	2.00
5	5.08

TRACER STUDY SITE PLAN
EST. 1202 CHEMONG

FIG. 4

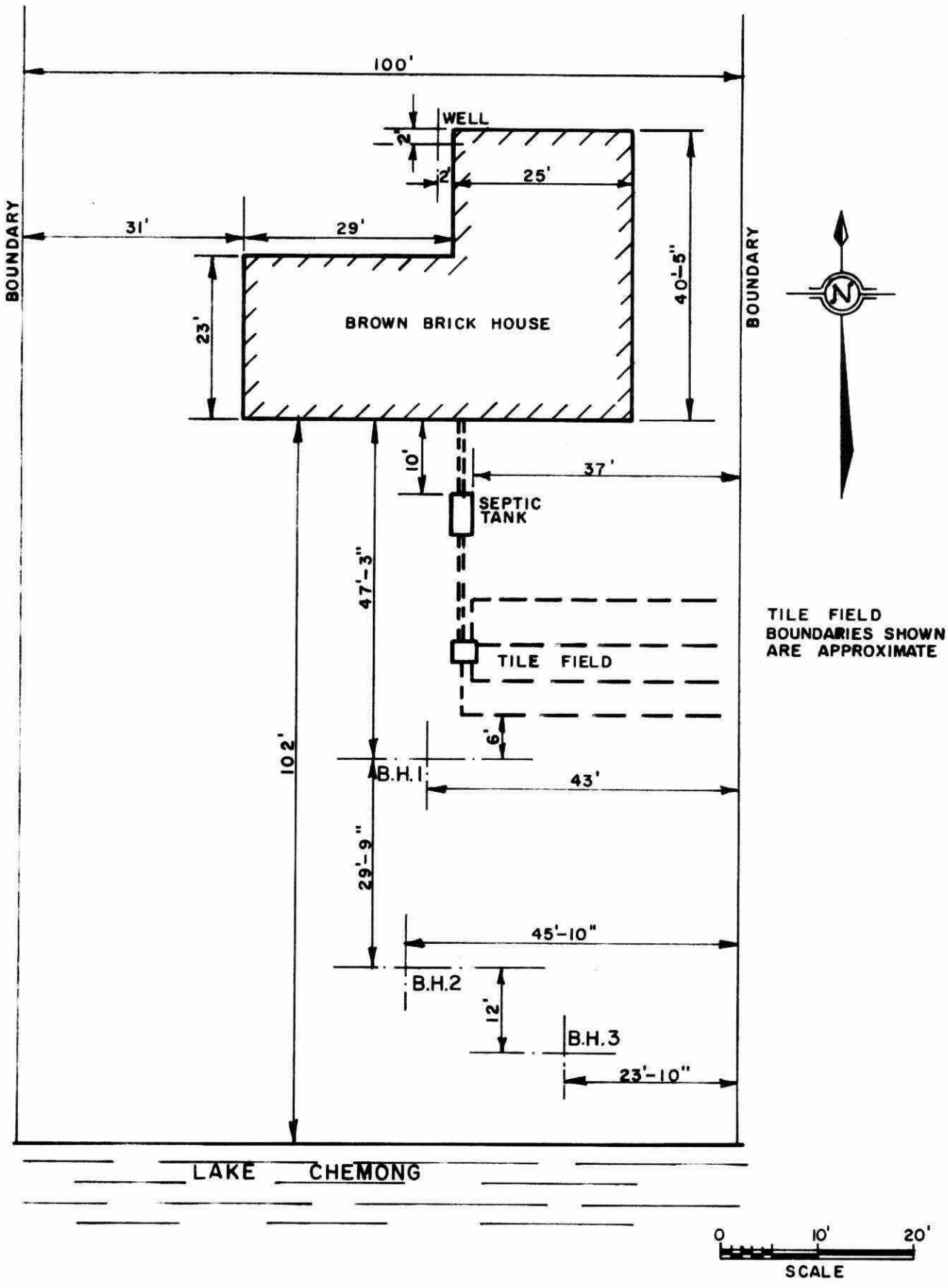


B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	5.00
2	4.08
3	3.00

TRACER STUDY SITE PLAN
EST. 1283 CHEMONG

FIG. 5



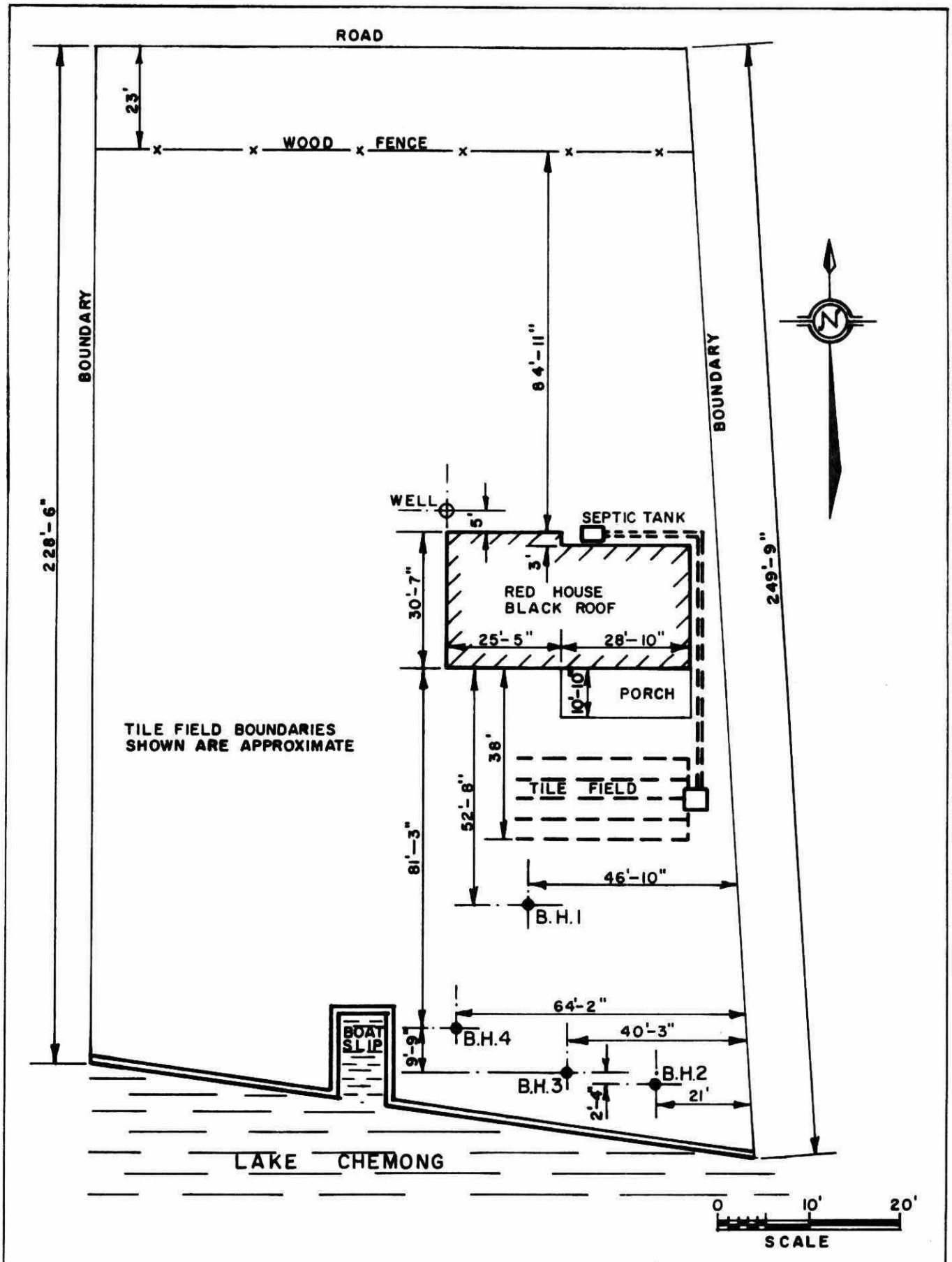
B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	5.00
2	4.33
3	4.25

TRACER STUDY SITE PLAN

EST. 1217 CHEMONG

FIG. 6



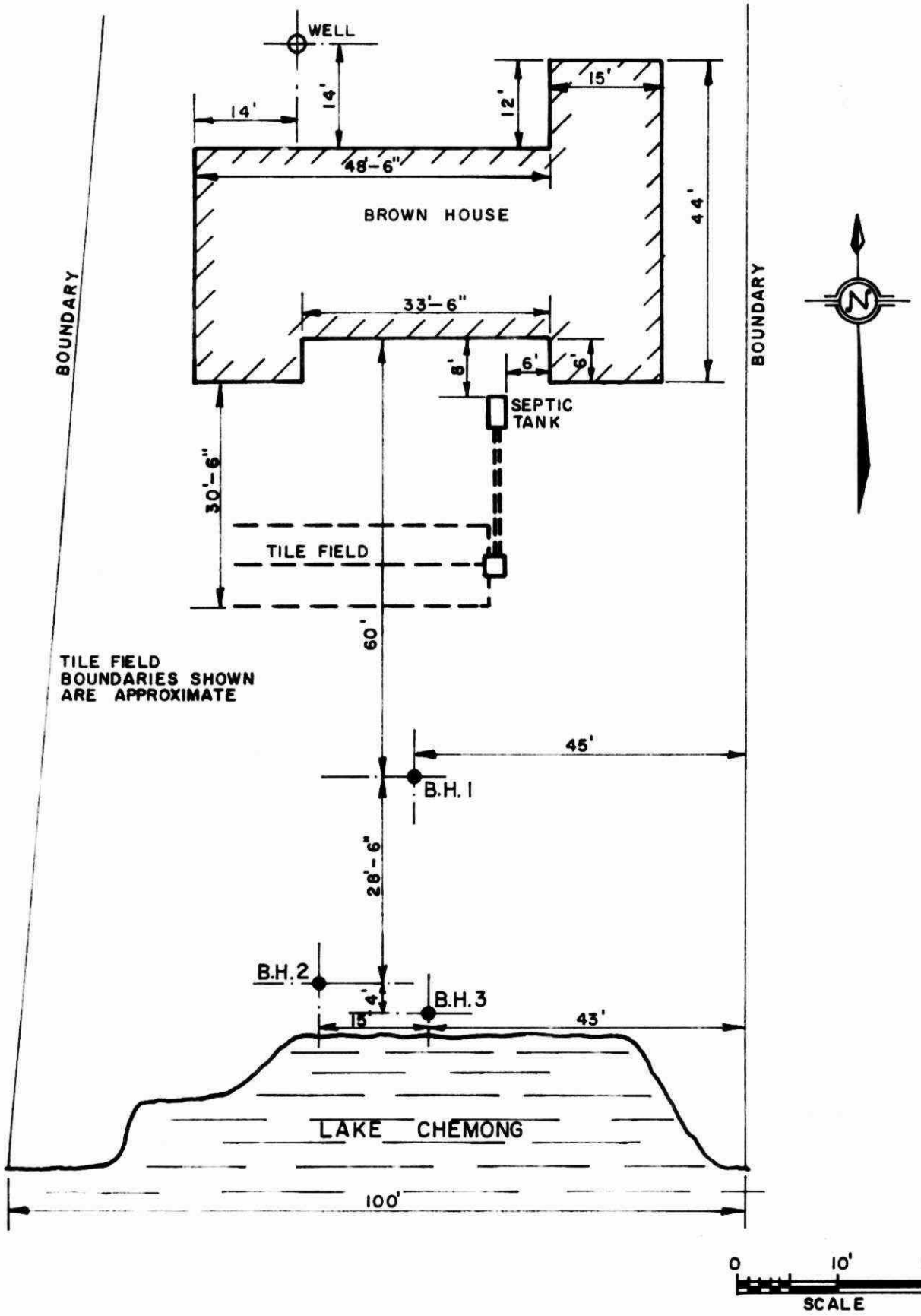
B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	4.25
2	2.42
3	5.5
4	5.0

TRACER STUDY SITE PLAN

EST. 1201 **CHEMONG**

FIG. 7

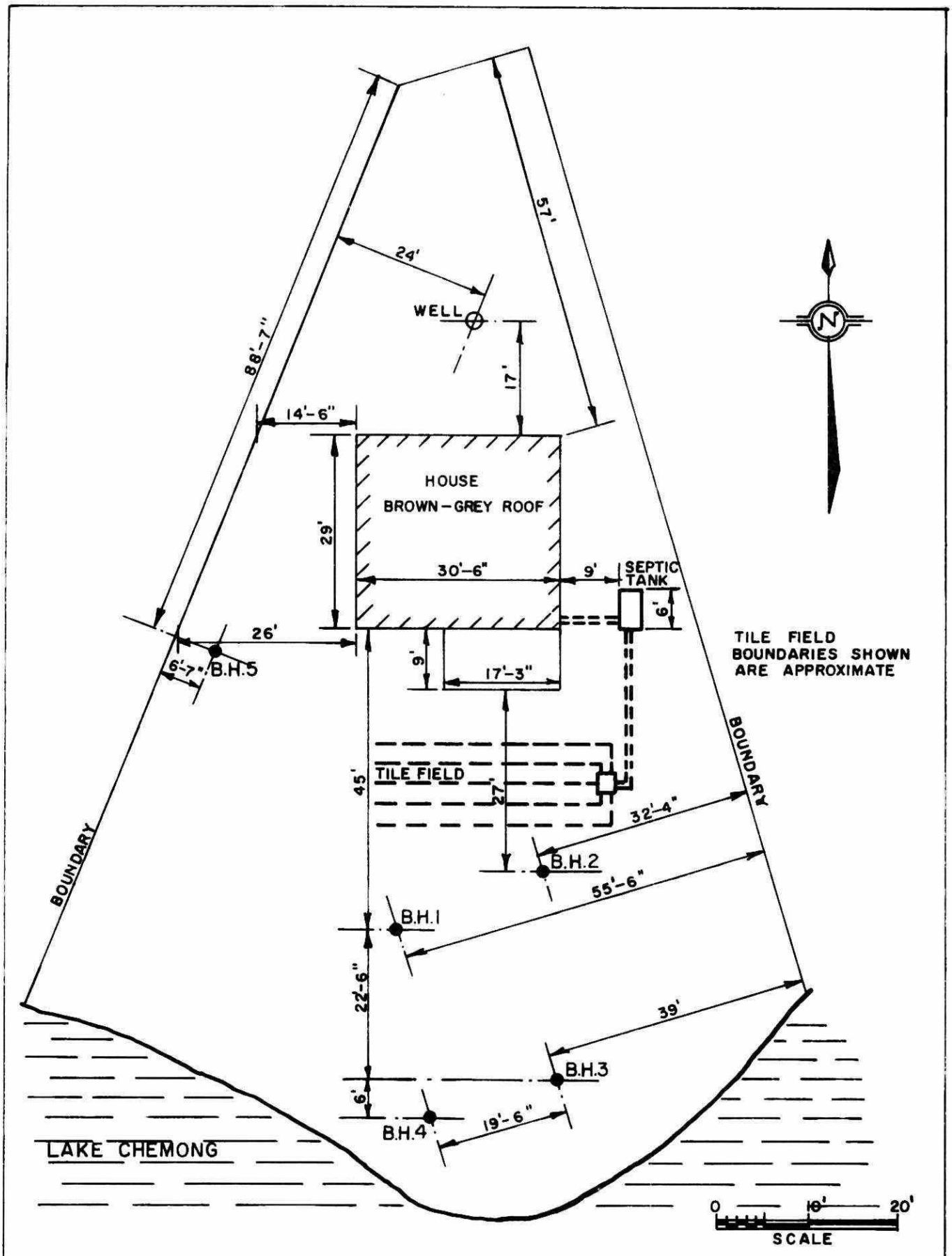


B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	4.58
2	4.75
3	3.00

TRACER STUDY SITE PLAN
EST. 1205 CHEMONG

FIG. 8

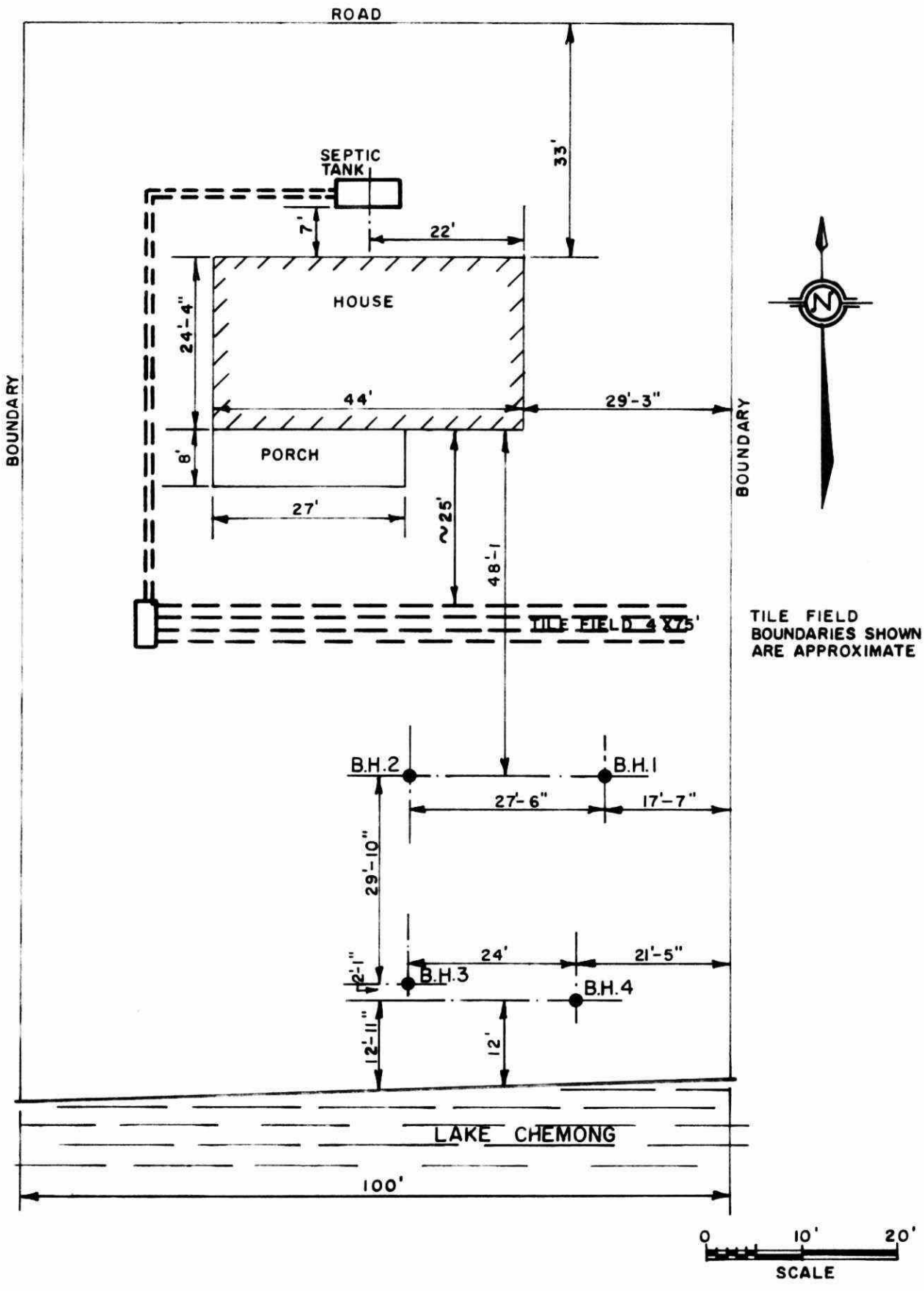


B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	5.0
2	6.0
3	4.0
4	5.0
5	5.0

TRACER STUDY SITE PLAN
EST. 13 CHEMONG

FIG. 9

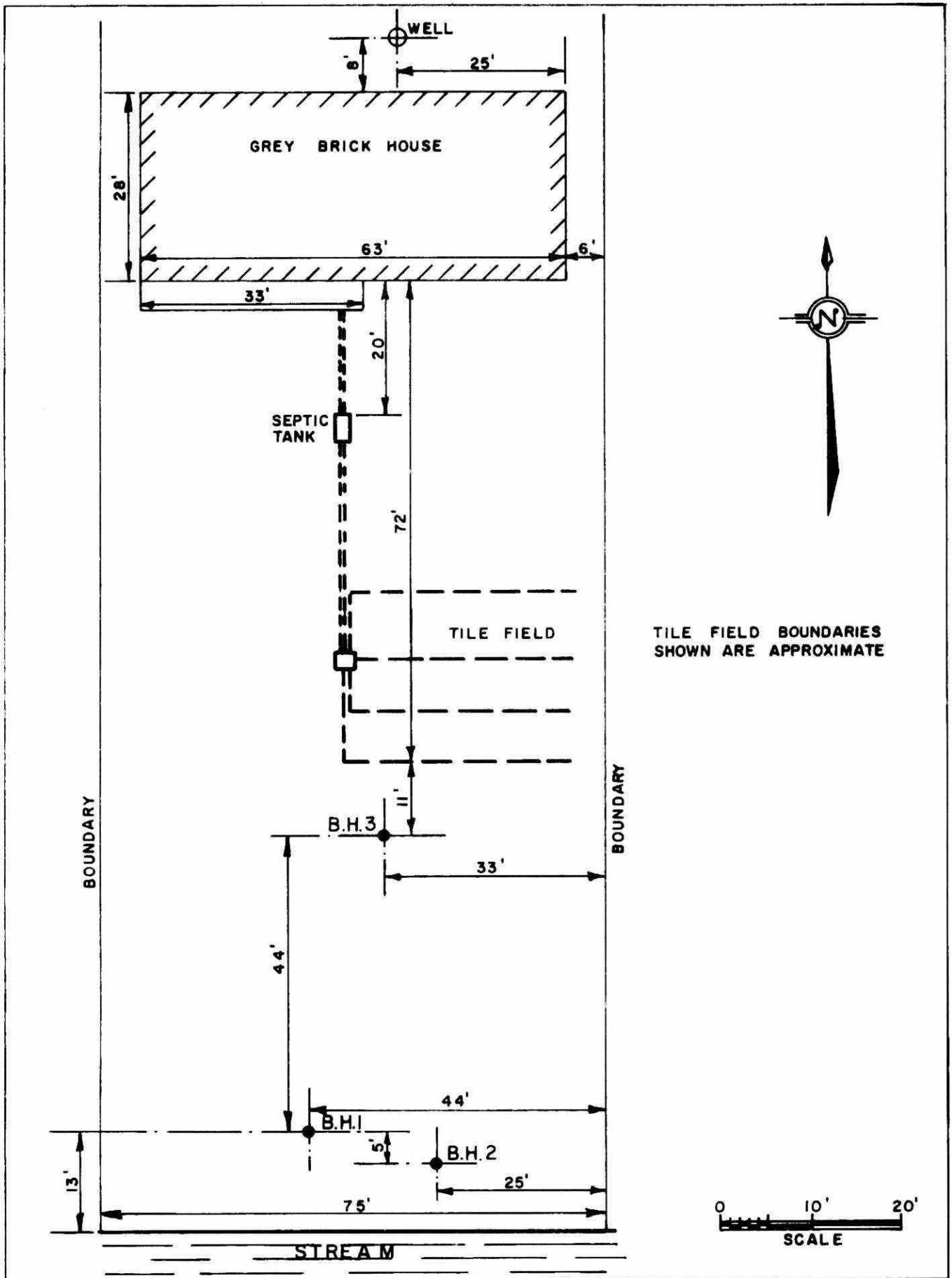


B.H. ● —— BOREHOLE

BORE HOLE	DEPTH IN FEET
1	6.0
2	5.5
3	5.0
4	4.5

TRACER STUDY SITE PLAN
EST. 1337 CHEMONG

FIG. 10



BORE HOLE	DEPTH IN FEET
1	12.8
2	10.8
3	9.3

TRACER STUDY SITE PLAN
GANANOQUE

FIG. 11

APPENDIX II

SOIL CHARACTERISTICS

4 Pages

Appendix II

SOIL CHARACTERISTICS

(Group I cottages)
(Imported fill material with stones and boulders)

	570 Bridgenorth	562 Bridgenorth	589 Bridgenorth
Depth to sampling point (only fill material between stones tested)	2'6" (0.76 m)	5'6" (1.68 m)	2' (0.61 m)
Grain Size Distribution			
Gravel			
Coarse (20-70 mm)	0	0	0
Fine (4.9-20 mm)	0	2	0
Sand			
Coarse (2.0-4.9 mm)	0	1	0
Medium (0.41-2.0 mm)	2	19	1
Fine (0.075-0.41 mm)	40	46	19
Silt (0.002-0.075 mm)	54	28	61
Clay (< 0.002 mm)	6	4	19
Eff. Size D_{10} mm	0.0054	0.0140	
Uniformity Coefficient C_u	14.44	18.57	

SOIL CHARACTERISTICS

(Group II cottages)
(Undisturbed natural soil)

	1202 Chemong	1283 Chemong	1217 Chemong
Depth to sampling point	2'6" (0.76 m)	1'6" (0.46 m)	4' (1.22 m)
Grain Size Distribution			
Gravel			
Coarse (20-70 mm)	0	0	0
Fine (4.9-20 mm)	0	1	4
Sand			
Coarse (2.0-4.9 mm)	1	1	4
Medium (0.41-2.0 mm)	1	5	8
Fine (0.075-0.41 mm)	13	52	38
Silt (0.002-0.075 mm)	73	30	36
Clay (<0.002 mm)	12	11	10
Eff. Size D_{10}mm			0.0024
Uniformity Coefficient C_u			50.0

SOIL CHARACTERISTICS

(Group II cottages)
(Undisturbed natural soil)

	1201 Chemong	1205 Chemong	1337 Chemong
Depth to sampling point	5' (1.52 m)	1'6" (0.46 m)	2'6" (0.76 m)
Grain Size Distribution			
Gravel			
Coarse (20-70 mm)	0	0	0
Fine (4.9-20 mm)	2	4	0
Sand			
Coarse (2.0-4.9 mm)	2	4	1
Medium (0.41-2.0 mm)	24	7	7
Fine (0.075-0.41 mm)	55	39	32
Silt (0.002-0.075 mm)	15	36	44
Clay (< 0.002 mm)	2	10	16
Eff. Size D_{10} mm	0.044	0.002	
Uniformity Coefficient C_u	7.04	60.0	

SOIL CHARACTERISTICS

(Group II cottages cont'd)
(Undisturbed natural soil)

	13 Chemong	Gananoque
Depth to sampling point	Not tested	9'10" (3.0 m)
Grain Size Distribution		
Gravel		
Coarse (20-70 mm)	Soil characteristics similar to those of adjacent lot 1201 Chemong.	0
Fine (4.9-20 mm)		0
Sand		
Coarse (2.0-4.9 mm		0
Medium (0.41-2.0 mm)		0
Fine (0.075-0.41 mm)		1
Silt (0.002-0.075 mm)		34
Clay (0.002 mm)		65
Eff. Size D_{10}mm		
Uniformity Coefficient C_u		

APPENDIX III

LABORATORY RESULTS

5 Pages

RESULTS OF TRACER STUDY ON LAKE CHEMONG AND ON ST. LAWRENCE RIVER

(JUNE 1 TO DECEMBER 31, 1972)

AVERAGE VALUES

NO.	Group	ESTABLISHMENT	Hole No.	Distance of hole from tile field	TRACERS No. of Samples	Tritium nCi/l	P-32 cpm/100ml	Fluorescein µg/l	CHEMICALS No. of Samples	P(as P) mg/l	NO_3(as N) mg/l	COLIFORMS No. of Samples	in 1000/100ml Total	Faecal
1	I	570 Bridgenorth	1	6'0" (1.83m)	44	Graph	No. 1	26.9	4	1.47	0.8	20	1,500.0	780.0
			2	26'4" (8.03m)	49	Graph	No. 2	9.3	5	1.30	2.8	24	440.0	40.0
			3	26'4" (8.03m)	53	Graph	No. 3	6.6	6	0.60	0.6	27	16.0	0.1
			4	Control Hole	53	N.D.**	3.8	5.0	8	0.70	5.1	26	190.0	6.0
			Well+		43	N.D.	4.0	1.6	0	-*	-	1	0	0
			Lake	53'10"(16.4m)	44	N.D.	3.5	3.0	7	0.12	<0.1	22	2.0	0.3
		Total number of samples			286				30			120		
2	I	562 Bridgenorth												
			1	Control Hole	0		Dried up		0	-	-	0	-	-
			2	in tile field	0		Dried up		0	-	-	3	8,000.0+	4,682.0
			3	in tile field	47	Graph	No. 4	1157.0	7	11.80	<0.1	40	6,292.0	759.0
			4	5'0" (1.52m)	0	-	-	-	2	14.50	<0.1	3	8,000.0+	2,372.0
			5	22'0" (6.71m)	47	Graph	No. 5	22.1	4	11.60	0.9	44	641.0	1.5
			6	20'0" (6.10m)	10		Dried up		0	-	-	7	340.0	45.5
			7	18'0" (5.48m)	46	N.D.	3.7	8.2	3	1.60	<0.1	36	53.0	1.7
			8	15'0" (4.57m)	52	N.D.	3.5	2.4	8	0.12	<0.1	39	11.0	0.1
			Well+		22	N.D.	3.5	4.3	0	-	-	1	0	0
			Lake	27'0" (8.23m)	35	N.D.	3.3	2.9	8	0.09	<0.1	41	2.4	0.2
					259				32			214		

* No analysis or no samples taken

** N.D. = NOT DETECTED

\+ drinking water well

RESULTS OF TRACER STUDY ON LAKE CHEMONG AND ON ST. LAWRENCE RIVER

(JUNE 1 TO DECEMBER 31, 1972)

AVERAGE VALUES

NO.	Group	ESTABLISHMENT	Hole No.	Distance of hole from tile field	TRACERS No. of Samples	Tritium nCi/l	P-32 cpm/100ml	Fluorescein µg/l	CHEMICALS No. of Samples	P(as P) mg/l	NO_3(as N) mg/l	COLIFORMS No. of Samples	in 1000/100ml Total	Faecal
3	I	589 Bridgenorth												
			1	12'0" (3.66m)		Graph	No. 6	4.8	7	0.38	0.1	36	14.2	0.3
			2	27'0" (8.23m)	0		Dried up		0	-	-	0	-	-
			3	34'0" (10.36m)	45	Graph	No. 7	3.8	8	0.15	0.1	38	116.6	0.1
			4	Control Hole	19	N.D.	3.4	2.9	6	0.70	0.8	23	90.6	36.8
			Well+		28	N.D.	3.4	1.7	0	-	-	2	0	0
			Lake	46'0" (14.02m)	36	N.D.	3.6	2.8	8	<0.10	0.1	38	0.7	0
		Total number of samples			128				29			137		
		Total samples tested for Group I			673				91			471		

RESULTS OF TRACER STUDY ON LAKE CHEMONG AND ON ST. LAWRENCE RIVER

(JUNE 1 TO DECEMBER 31, 1972)

AVERAGE VALUES

NO.	Group	ESTABLISHMENT	Hole No.	Distance of hole from tile field	TRACERS No. of Samples	Tritium nC/l	P-32 cpm/100ml	Fluorescein µg/l	CHEMICALS No. of Samples	P(as P) mg/l	NO_3(as N) mg/l	COLIFORMS No. of Samples	in 1000/100ml Total	Faecal
4	II	1202 Bridgenorth												
			1	7'0" (2.13m)	45	Graph	No. 8	4.4	10	0.47	0.1	23	1,052.0	40.9
			2	50'0" (15.24m)	0		Dried up		0	-	-	0	-	-
			3	25'0" (7.62m)	41	N.D.	2.9	2.8	9	0.29	0.1	18	56.4	4.5
			4	30'0" (9.14m)	0		Dried up		0	-	-	0	-	-
			5	45'0" (13.72m)	37	N.D.	2.9	2.6	6	0.24	8.6	16	2.3	0
			Well +		36	N.D.	3.0	1.0	2	0.05	17.5	0	-	-
			Lake	69'0" (21.03m)	38	N.D.	3.5	2.9	6	0.05	0.1	22	1.1	0.1
		Total number of samples			197				33			79		
5	II	1283 Chemong												
			1	16'0" (4.88m)	18	Graph	No. 9	4.5	7	0.34	0.3	43	0.1	0
			2	38'0" (11.58m)	18	N.D.	3.2	3.8	7	0.80	< 0.1	44	0.4	0
			3	49'0" (14.94m)	8	N.D.	3.3	5.0	4	0.04	0.2	22	2.2	0
			Well +		14	N.D.	3.6	1.3	0	-	-	2	0	0
			Lake	69'0" (21.03m)	18	N.D.	3.6	3.0	7	0.18	< 0.1	44	1.2	0
		Total number of samples			76				25			155		
6	II	1217 Chemong												
			1	69'0" (1.83m)	0		Dried up		0	-	-	0	-	-
			2	35'0" (10.67m)	13	N.D.	3.9	3.7	7	0.85	18.9	20	9.6	1.1
			3	47'9" (14.55m)	13	N.D.	4.0	4.6	8	0.25	4.1	21	10.8	0
			Well +		16	N.D.	3.4	0.7	0	-	-	0	-	-
			Lake	60'9" (18.52m)	19	N.D.	3.7	2.7	7	0.06	< 0.1	40	1.2	0.1
		Total number of Samples			61				22			81		

RESULTS OF TRACER STUDY ON LAKE CHEMONG AND ON ST. LAWRENCE RIVER

(JUNE 1 TO DECEMBER 31, 1972)

AVERAGE VALUES

NO.	Group	ESTABLISHMENT	Hole No.	Distance of hole from tile field	TRACERS No. of Samples	Tritium nCi/l	P-32 cpm/100ml	Fluorescein µg/l	CHEMICALS No. of Samples	P(as P) mg/l	NO_3(as N) mg/l	COLIFORMS No. of Samples	in 1000/100ml Total	Faecal
7	II	1201 Chemong												
			1	14'0" (4.27m)	17	N.D.	3.6	6.3	5	0.42	5.2	42	6.8	0.9
			2	55'0" (16.76m)	2	N.D.	2.9	13.0	0	-	-	4	0.7	0
			3	52'8" (16.05m)	20	N.D.	3.7	5.6	7	0.31	< 0.1	46	1.8	0.1
			4	43'0" (13.10m)	17	N.D.	4.5	10.7	4	0.07	< 0.1	18	0.2	0
			Well+		16	N.D.	3.3	1.9	0	-	-	0	-	-
			Lake	60'0" (18.29m)	18	N.D.	4.0	3.3	7	0.07	< 0.1	20	0.4	0
		Total number of samples			90				23			130		
8	II	1205 Chemong												
			1	23'0" (7.01m)	14	N.D.	3.7	2.4	7	0.45	11.0	37	0.6	0
			2	57'6" (17.53m)	14	N.D.	3.7	6.7	6	0.27	< 0.1	38	0.6	0
			3	55'6" (16.92m)	14	N.D.	4.0	9.2	6	1.20	< 0.1	38	4.9	0
			Well+		12	N.D.	4.4	2.0	0	-	-	0	-	-
			Lake	59'0" (17.98m)	14	N.D.	4.0	3.0	6	0.12	< 0.1	39	1.6	0
		Total number of samples			68				25			152		
9	II	13 Chemong												
			1	15'0" (4.57m)	18	N.D.	3.8	2.7	12	0.33	< 0.1	40	94.1	27.7
			2	7'0" (2.13m)	5	N.D.	4.2	2.1	1	0.10	0.3	10	3.9	0
			3	38'0" (11.58m)	18	N.D.	3.7	7.0	11	0.20	< 0.1	40	2.2	0
			4	44'0" (13.41m)	0		Dried up		0	-	-	0	-	-
			5	Control Hole	15	N.D.	3.4	3.6	8	1.11	5.8	34	58.3	0.3
			Well+		4	N.D.	2.7	1.8	0	-	-	1	0.1	0
			Lake	51'6" (15.70m)	16	N.D.	3.7	3.0	9	0.18	< 0.1	40	2.7	0.1
		Total number of samples			76				41			165		

RESULTS OF TRACER STUDY ON LAKE CHEMONG AND ON ST. LAWRENCE RIVER

(JUNE 1 TO DECEMBER 31, 1972)

AVERAGE VALUES

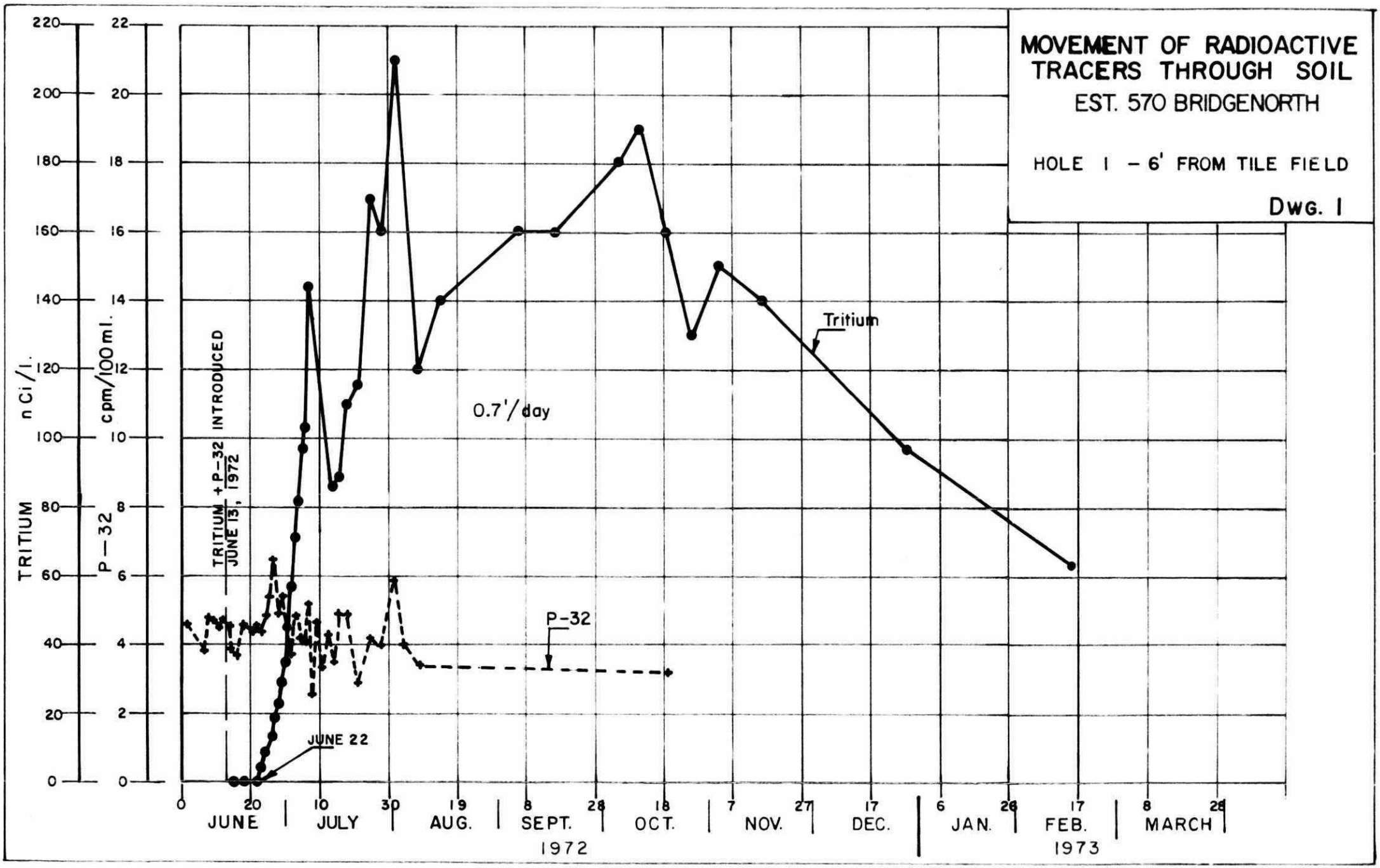
NO.	Group	ESTABLISHMENT	Hole No.	Distance of hole from tile field	TRACERS No. of Samples	Tritium nCi/l	P-32 cpm/100ml	Fluorescein µg/l	CHEMICALS No. of Samples	P(as P) mg/l	NO_3(as N) mg/l	COLIFORMS No. of Samples	in 1000/100ml Total	Faecal
10	II	1337 Chemong												
			1	20'0" (6.09m)	17	N.D.	3.6	3.1	10	0.34	0.4	33	0.7	0
			2	20'0" (6.09m)	16	N.D.	3.6	4.0	10	0.25	10.0	27	4.4	0
			3	50'0" (15.24m)	18	N.D.	3.6	2.3	11	0.09	7.7	40	7.3	0.6
			4	52'0" (15.85m)	18	N.D.	3.8	1.7	11	0.12	0.3	40	3.9	0.5
			Well+		13	N.D.	3.7	1.2	0	-	-	0	-	-
			Lake	65'0" (19.81m)	16	N.D.	4.0	2.6	11	0.09	<0.1	39	1.1	0
		Total number of samples			98				53			179		
11	II	Gananoque												
			1	55'0" (16.76m)	70	N.D.	3.5	4.7	11	0.12	0.2	59	38.5	0.6
			2	60'0" (18.29m)	67	N.D.	3.6	1.5	11	0.15	0.3	60	1.3	0
			3	11'0" (3.35m)	69	Graph	No. 10	14.0	11	0.19	<0.1	60	26.2	0.2
			Well+		15	N.D.	2.7	0.8	0	-.19	-.1	0	-	-
			Lake	68'0" (20.73m)	16	N.D.	3.0	2.9	0	-	-	0	-	-
		Total number of samples			237				33			179		
		Total samples tested for Group II			903				255			1120		
		Total samples tested in 1972 Study			1576				346			1591		

APPENDIX IV

GRAPHS

(Movement of Radioactive
Tracers Through Soil)

10 Drawings

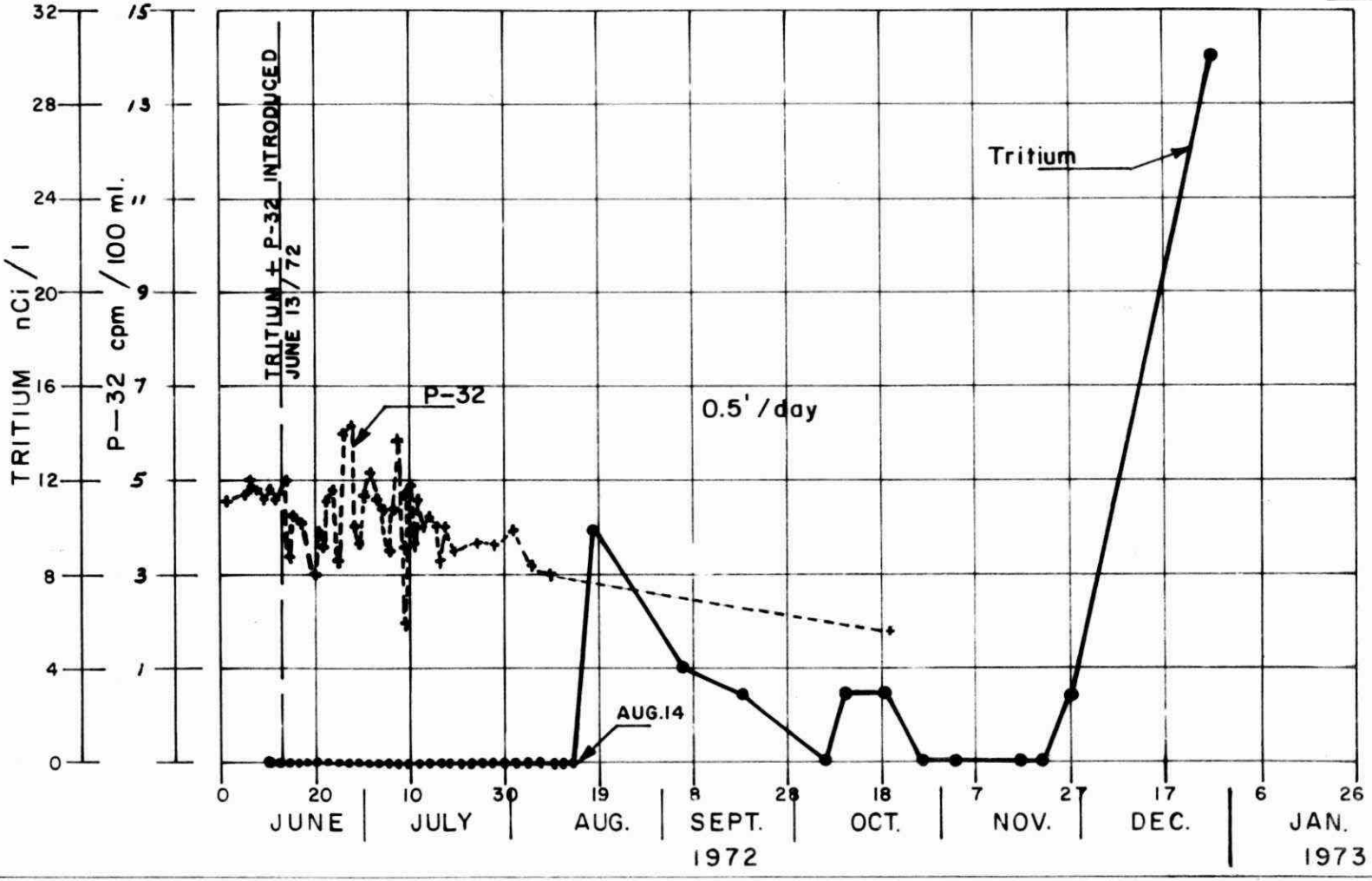

MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL
EST. 570 BRIDGENORTH
HOLE 1 – 6' FROM TILE FIELD
DWG. 1
TRITIUM nCi/l.
P–32 cpm/100ml.
TRITIUM + P–32 INTRODUCED JUNE 13, 1972
0.7'/day
Tritium
P–32
JUNE 22
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
1972
1973

MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 570 BRIDGENORTH

HOLE 2 26'-4" FROM TILE FIELD

Dwg. 2

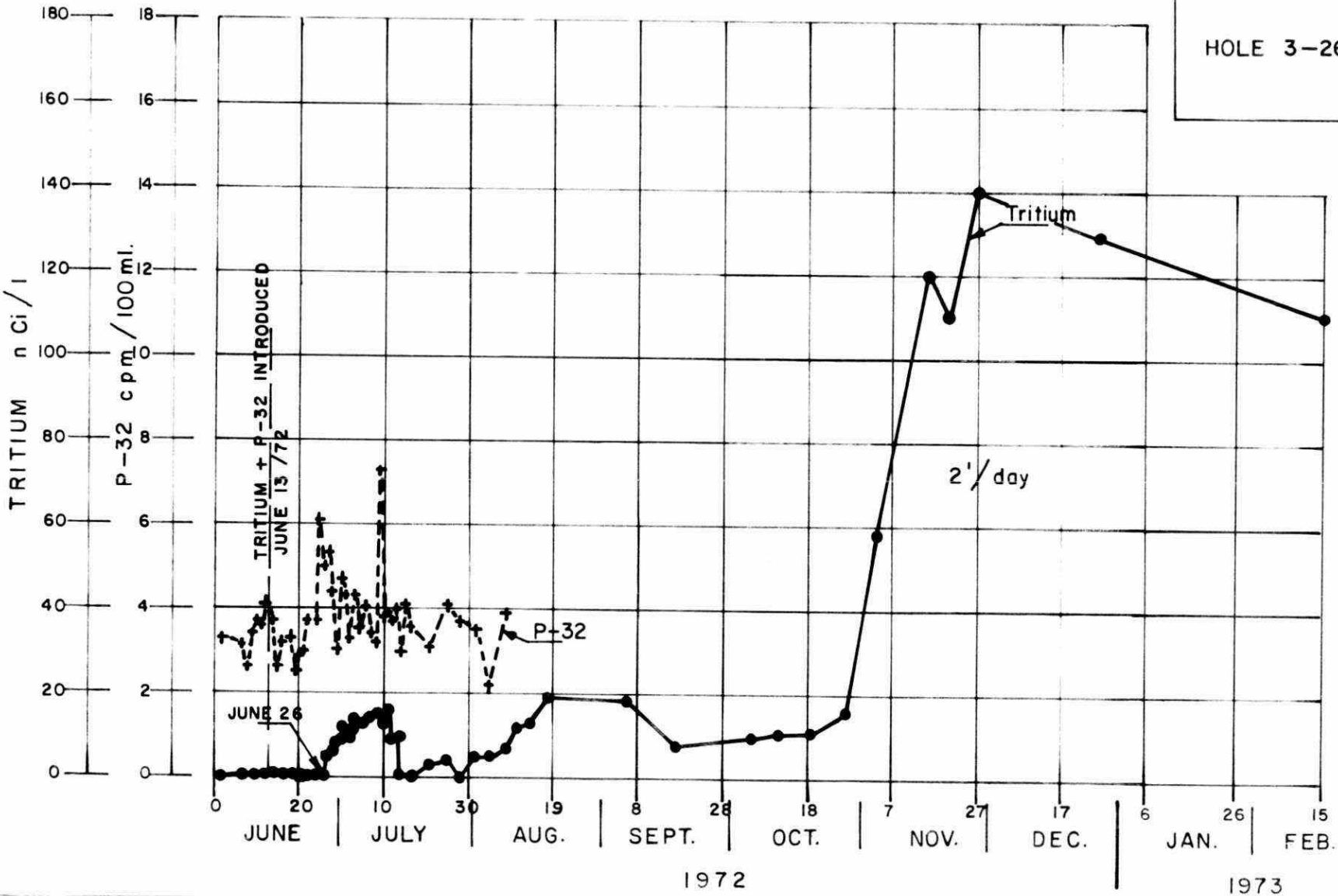


MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 570 BRIDGENORTH

HOLE 3–26'-4" FROM TILE FIELD

DWG. 3

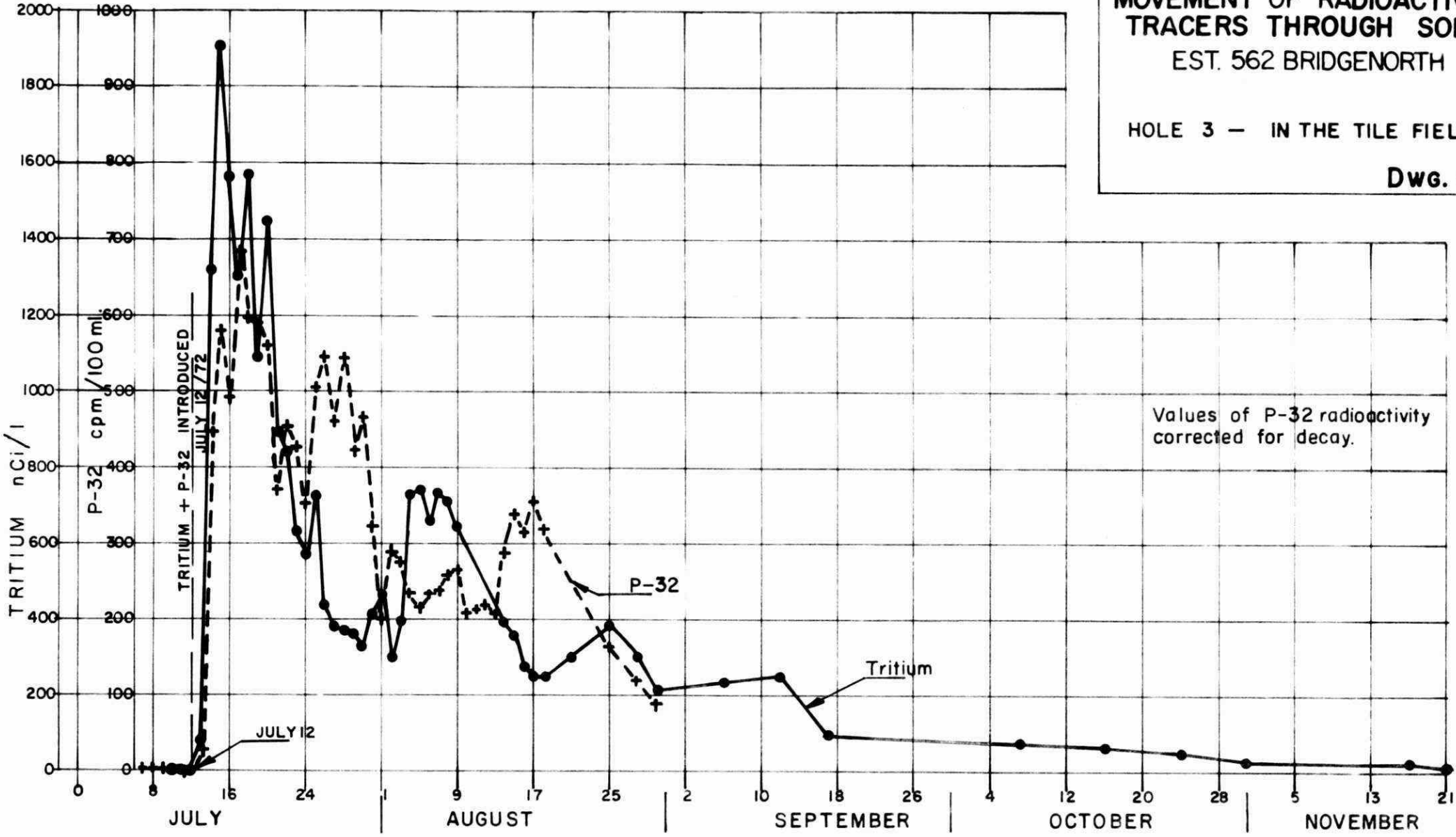


MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 562 BRIDGENORTH

HOLE 3 — IN THE TILE FIELD

DWG. 4

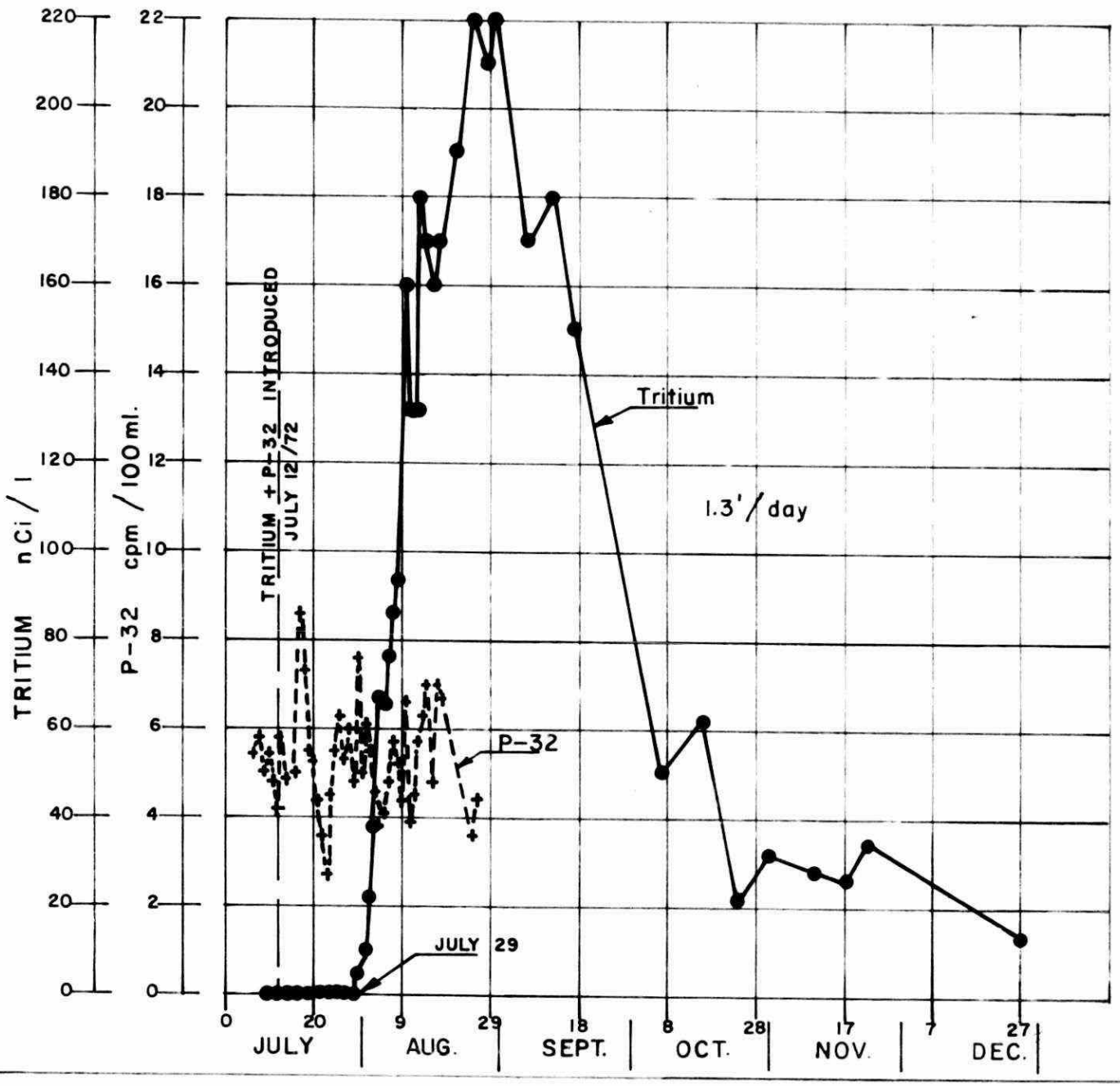


MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 562 BRIDGENORTH

HOLE 5 – 22' FROM TILE FIELD

DWG. 5

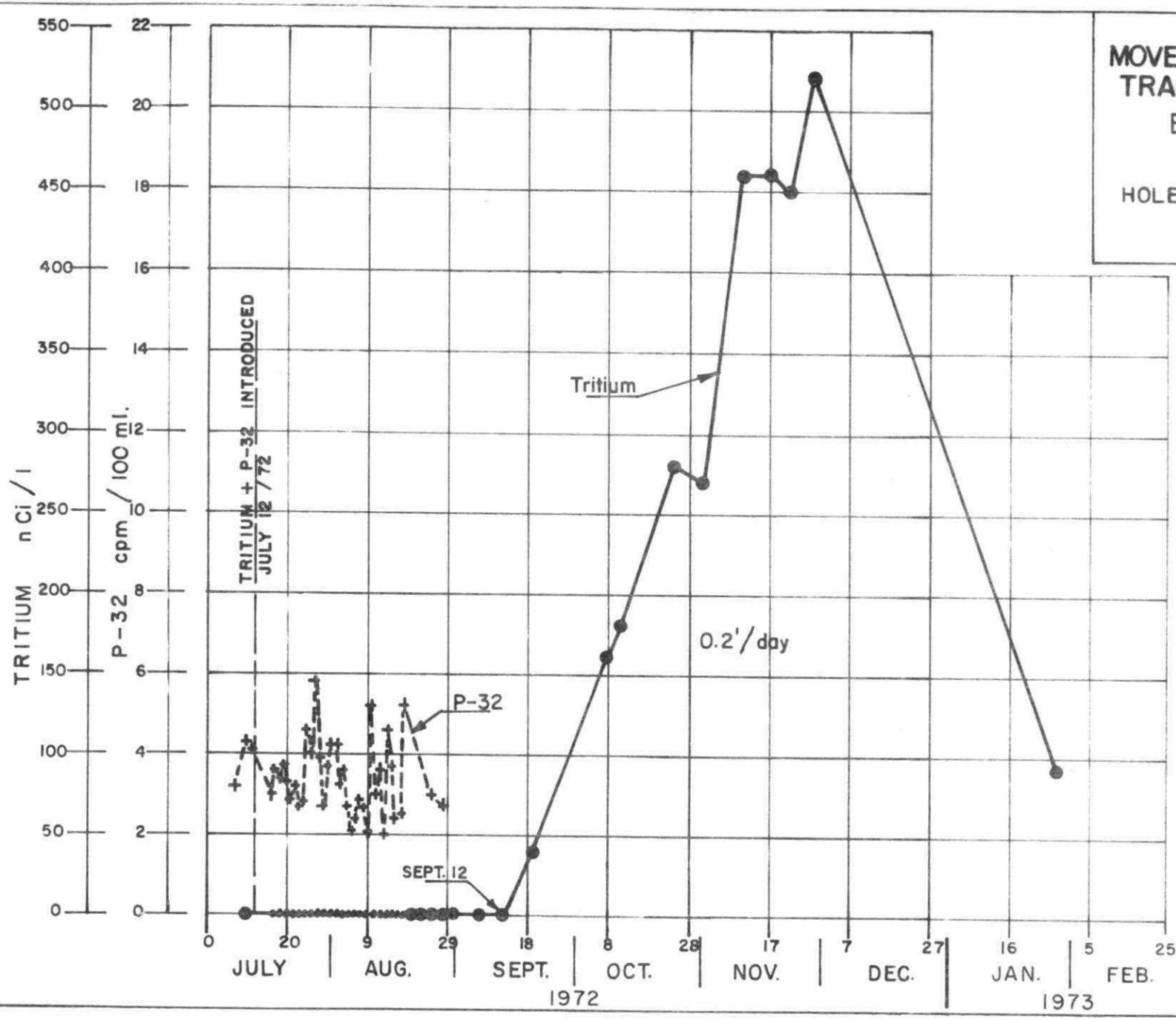


MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 589 BRIDGENORTH

HOLE 1 — 12' FROM TILE FIELD

DWG. 6

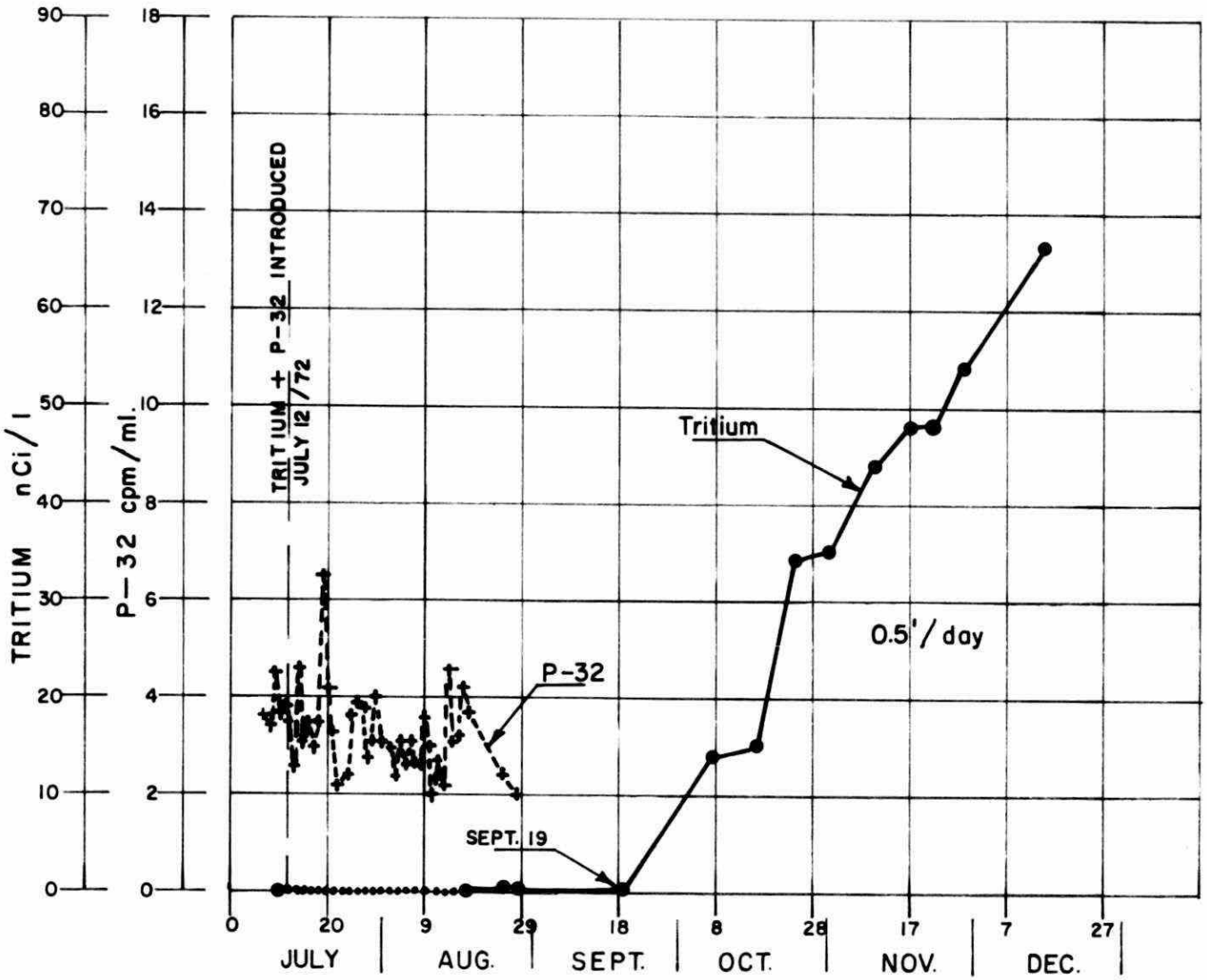


MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 589 BRIDGENORTH

HOLE 3 -34' FROM TILE FIELD

DWG. 7

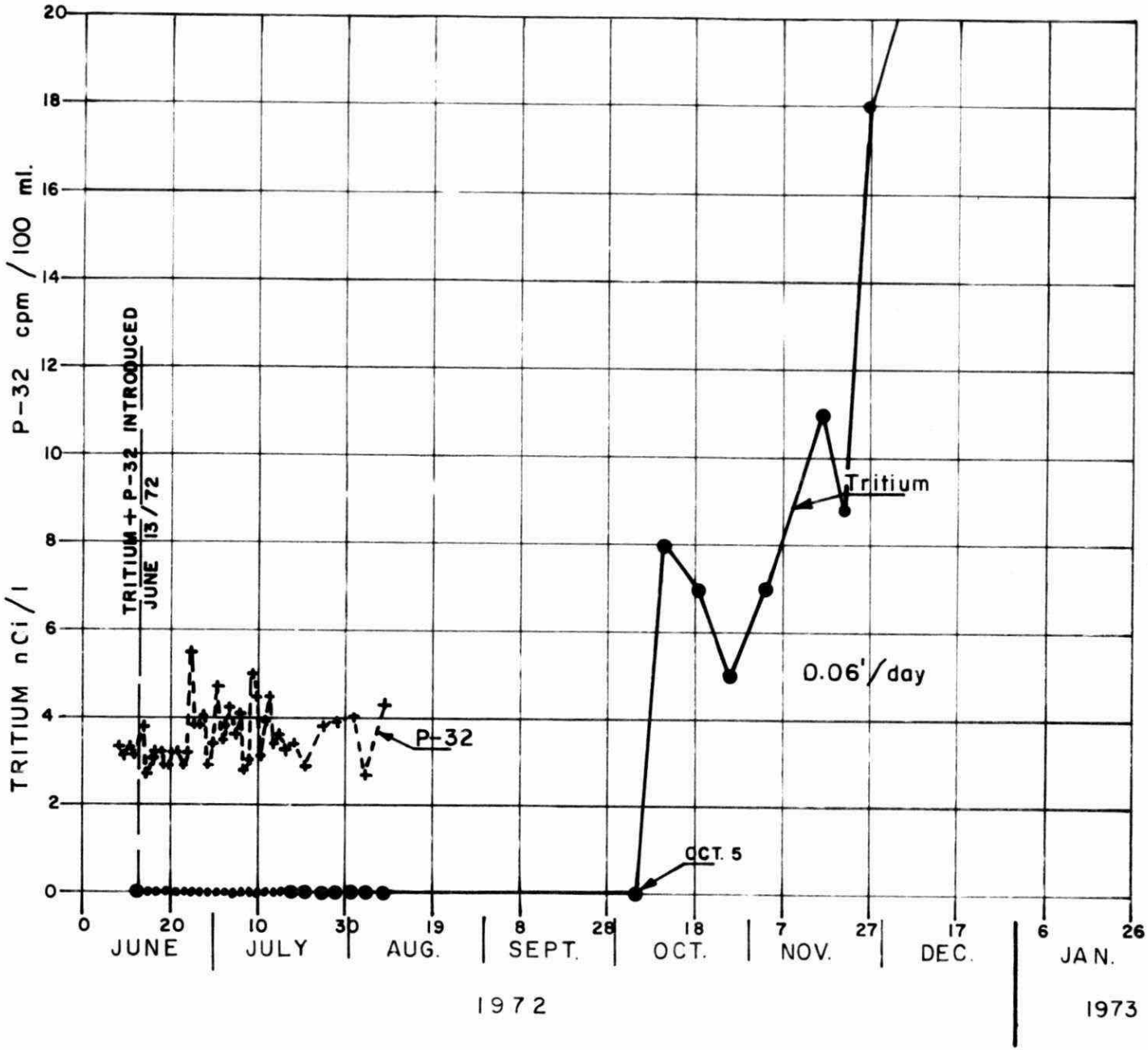


MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 1202 **CHEMONG**

HOLE 1 – 7' FROM TILE FIELD

Dwg. 8

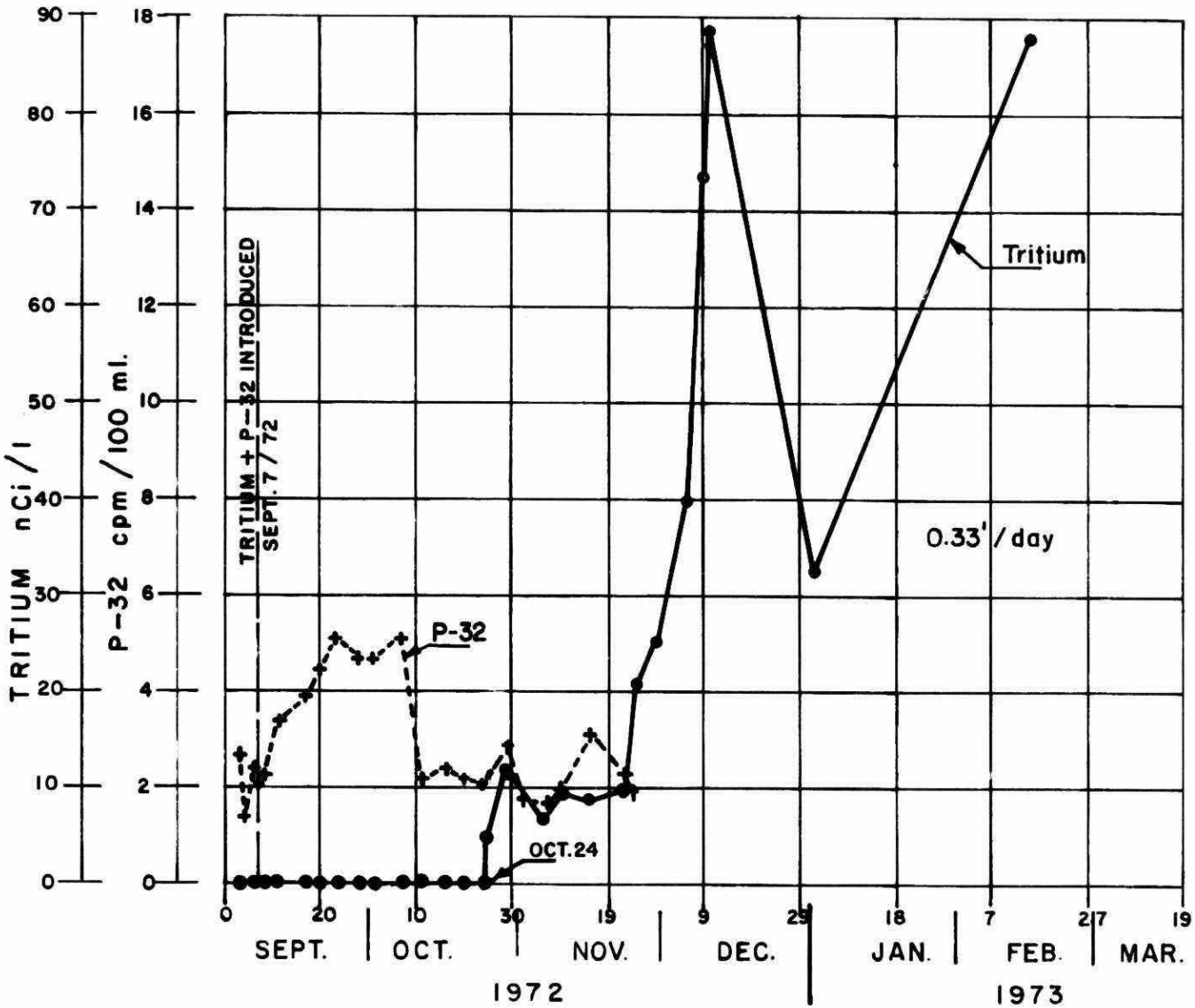

P-32 cpm / 100 ml.
TRITIUM nCi / l
TRITIUM + P-32 INTRODUCED JUNE 13/72
P-32
Tritium
0.06' / day
OCT. 5
0 2 4 6 8 10 12 14 16 18 20
0 20 10 30 19 8 28 18 7 27 17 6 26
JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN.
1972
1973

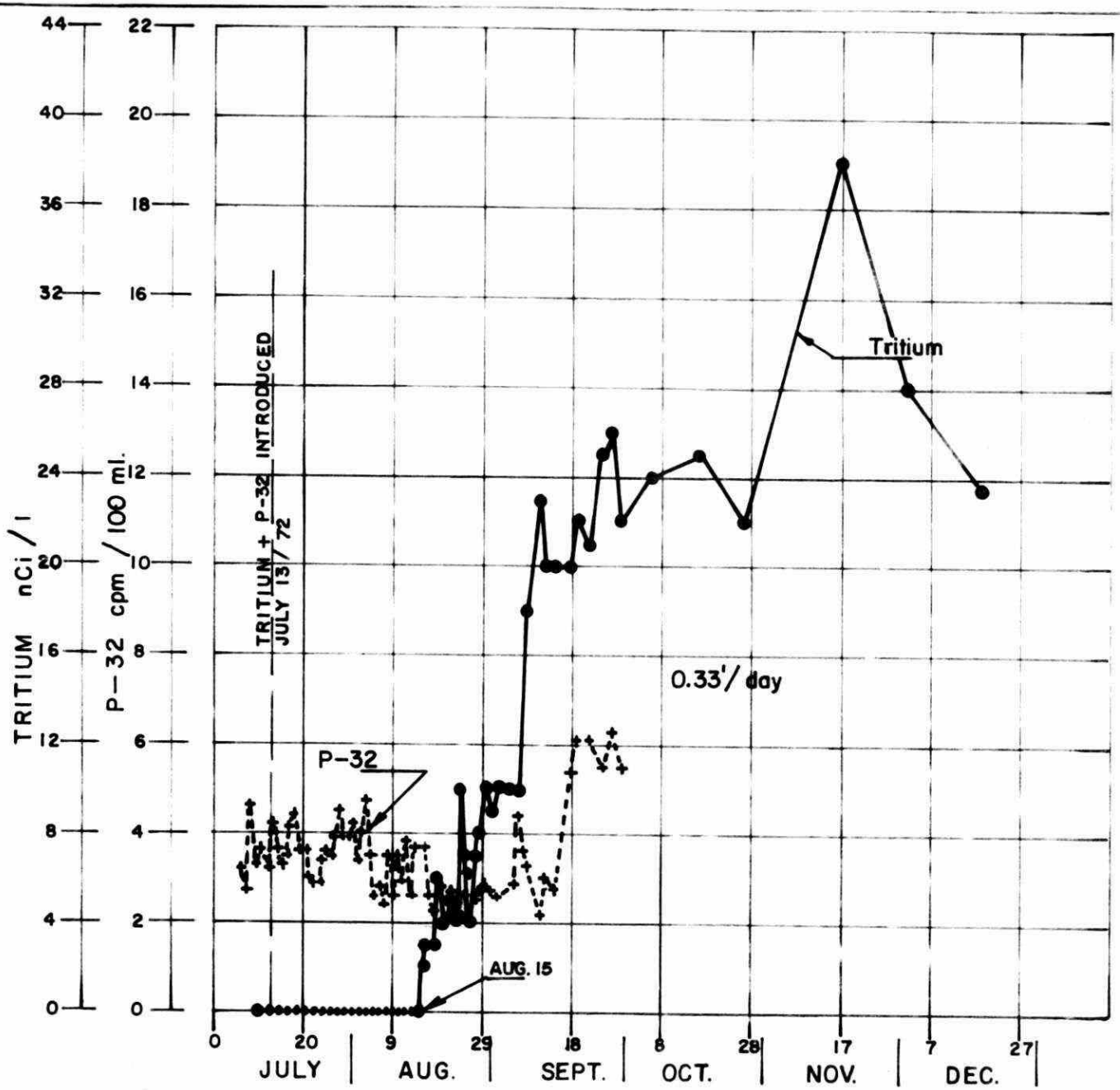
MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

EST. 1283 **CHEMONG**

HOLE 1 – 16' FROM TILE FIELD

DWG. 9





MOVEMENT OF RADIOACTIVE TRACERS THROUGH SOIL

GANANOQUE

HOLE 3 — 11' FROM TILE FIELD

DWG. 10

TD
761
B73
S78
1973